April 30, 2010

Structural Implications of Mounting Solar Panels on a Residential Wood Structure

Forward

Thank you Andrea Luecke, the City of Milwaukee, WE Energy, Attendees, and the US Department of Energy for the opportunity to present this material.

Regardless of how one may quantify the benefits of renewable energies it is our duty as engineers, installers, and code officials to take into account all aspects of the installation. This includes the impact on the existing structure.

This material should, at the very least, make one aware of the potential to do harm and instill the need to address the building structure.

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The following information, calculations, drawings, and conclusions are part of an educational seminar intended to present a process. No claim is being made as to their accuracy or relevance as errors have been discovered since their creation. In addition no information should be taken from the, drawings, tables or code excerpts due to the potential for them to be incomplete, out of date, or still under development. Consult your local building official for the current and complete information.

Objectives & Scope

To present the process by which a structural engineer might evaluate a buildings ability to support solar hot water or photo voltaic equipment.

To provided examples of drawings and calculations that could be an important part of the permitting process.

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Limited to:

- Residential structures as defined and governed by the Uniform Dwelling Code of Wisconsin Administrative Code (UDC)
- Flush mounted flat solar panels
  - Photo Voltaic
  - Solar Hot Water
- Wood Construction
  - Simple Trusses or Rafters

The calculations and drawings presented here have not been checked and could contain errors.

PRESENTATION

Today's presentation is intended to provide a process from which a determination can be made as to a building's ability to support solar equipment. This process can incorporate many complicated mathematical calculations and the designer should be aware of their own, as well as their insurance policies, limitations:

Wisconsin Administration Code Requirements

Based on my review and conversations with building officials:

- Calculations may be required by a building official but they do not need to be created by a registered professional engineer.
- UDC can be interpreted and a permit application submitted by a contractor, designer or owner
- For all new construction, the Code must be satisfied as a minimum
- Existing construction that does not meet the minimum ode requirements is not required to be brought within compliance but no increased or new loads can be imparted on it.
- Structural elements that do not conform to the Code cannot be modified in such a way that decrease their strength.

Wisconsin Administration Code

Chapter Comm 20

ADMINISTRATION AND ENFORCEMENT

Note: Chapter ILHR 20 was renumbered chapter Comm 20 under s. 13.93 (2m) (b) 1., Stats., and corrections made under s. 13.93 (2m) (b) 6. and 7., Stats., Register, January, 1999, No. 517.

Subchapter I — Purpose and Scope

Comm 20.01 Purpose. (1) The purpose of this code is to establish uniform statewide construction standards and inspection procedures for one− and 2−family dwellings and modular homes in accordance with the requirements of ss. 101.60 and 101.70, Stats.

(2) The purpose of this code is to establish uniform installation and inspection procedures for manufactured homes in accordance with the requirements of s. 101.96, Stats.

Note: The design and construction of manufactured homes is regulated by the federal Department of Housing and Urban Development under Title 24 CFR Part 3280.

Note: See ch. Comm 5 for licensing requirements for manufactured home manufacturers and manufactured home installers.

Note: Other agencies may have regulations that affect the design, construction or placement of the dwelling and accessory structures or systems serving the dwelling. The regulations may necessitate additional administrative procedures or inspections for compliance.

History: Cr. Register, November, 1979, No. 287, eff. 6−1−80; am. Register, March, 1992, No. 433, eff. 4−1−92; CR 06−071: renum. s. Comm 20.01 to be (1), cr. (2) Register December 2006 No. 612, eff. 4−1−07; correction in (1) made under s. 13.92 (4) (b) 7., Stats., Register March 2009 No. 639.

Comm 20.02 Scope. (1) General. The provisions of this code apply to all of the following:

(a) All one− and 2−family dwellings built on or after the effective dates under s. Comm 20.03.

Note: This includes site−built dwellings, manufactured buildings used as dwellings, modular homes and dwellings that may be designated as cabins, seasonal homes, temporary residences, etc., (except for manufactured or HUD homes, which are covered separately under this section).

(b) Adult family homes providing care, treatment and services for 3 or 4 unrelated adults built on or after the effective dates under s. Comm 20.03.

(c) Community−based residential facilities providing care, treatment and services for 5 to 8 unrelated adults built on or after the effective dates under s. Comm 20.03.

(d) The onsite installation of a mobile home or manufactured home on piers, regardless of the date of production of the home.

Note: The design and construction of a manufactured home is regulated by the U.S. Department of Housing and Urban Development and is not subject to UDC requirements. Prior to regulation by HUD in 1976, manufactured homes were known as mobile homes and their design and construction were not uniformly regulated. See s. Comm 20.07 (52m) for the statutory definition.

(e) The onsite installation of a manufactured home, regardless of the type of foundation, where the manufactured home has a production date on or after April 1, 2007.

(f) The design and construction of a crawlspace, basement or foundation, other than piers, under a manufactured home where the manufactured home has a production date on or after the effective dates under s. Comm 20.03.

(g) All garages, carports, porches, stoops, decks, balconies, stairways and similar structures that are attached to any building covered under this section that was constructed or had a production date on or after the effective dates under s. Comm 20.03.

(h) Adjacent, unattached structures listed under par. (g) that serve an exit from a dwelling.

(2) Municipal ordinances. (a) A municipality may not adopt an ordinance on any subject falling within the scope of this code including establishing restrictions on the occupancy of dwellings for any reason other than noncompliance with the provisions of this code as set forth in s. Comm 20.10 (4). This code does not apply to occupancy requirements occurring after the first occupancy for residential purposes following the final inspection required under s. Comm 20.10 (3) (h)

(b) This code shall not be construed to affect local requirements relating to land use, zoning, post−construction storm water management, fire districts, side, front and rear setback requirements, property line requirements or other similar requirements. This code shall not affect the right of municipalities to establish safety regulations for the protection of the public from hazards at the job site.

(c) Any municipality may, by ordinance, require permits and fees for any construction, additions, alterations or repairs not within the scope of this code.

(d) Any municipality may, by ordinance, adopt the provisions of chs. Comm 20 to 25 to apply to any additions or alterations to existing dwellings.

(e) Nothing in this chapter shall prevent a municipality from any of the following:

1. Implementing erosion and sediment control requirements that are more stringent than the standards of this code when directed by an order of the United States Environmental Protection Agency or by an administrative rule of the department of natural resources under s. NR 151.004.

2. Regulating erosion and sediment control for sites that are not under the scope of this chapter.

- Become familiar with the entire Code – it can only help you

www.legis.state.wi.us/rsb/code/comm/comm020.html

- Typically Chapters 20, 21 and the appendices are the most applicable
- “Work shall be done in a workmanlike manner”
  - Become familiar with all structure affected by installation of solar equipment
  - Follow load path through foundation
  - Don’t apply additional loads to non-Code compliant, damaged, or questionable structural elements without providing adequate reinforcement

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

- Most of the information needed is located in Chapter 21 and Appendices

Chapter Comm 21

CONSTRUCTION STANDARDS

Note: Chapter Ind 21 was renumbered to be chapter ILHR 21, Register, February, 1985, No. 350, eff. 3–1–85. Chapter ILHR 21 was renumbered chapter Comm 21 under s. 13.93 (2m) (b) 1., Stats., and corrections made under s. 13.93 (2m) (b) 6. and 7., Stats., Register, January, 1999, No. 517. **Chapter Comm 21 was reprinted to correct the Table of Contents, Register October 2009 No. 646.**

Subchapter I — Scope

Comm 21.01 Scope. The provisions of this chapter shall apply to the design and construction of all one– and 2–family dwellings.

History: Cr. Register, November, 1979, No. 287, eff. 6–1–80.

Subchapter II — Design Criteria

Comm 21.02 Loads and materials. Every dwelling shall be designed and constructed in accordance with the requirements of this section.

(1) DESIGN LOAD. Every dwelling shall be designed and constructed to support the actual dead load, live loads and wind loads acting upon it without exceeding the allowable stresses of the material. The construction of buildings and structures shall result in a system that provides a complete load path capable of transferring all loads from point of origin through the load–resisting elements to the foundation.

(a) *Dead loads.* Every dwelling shall be designed and constructed to support the actual weight of all components and materials. Earth–sheltered dwellings shall be designed and constructed to support the actual weight of all soil loads.

(b) *Live loads.* 1. Floors and ceilings. Floors and ceilings shall be designed and constructed to support the minimum live loads listed in Table 21.02. The design load shall be applied uniformly over the component area.

TABLE 21.02

Component	Live Load (pounds per sq. ft.)
Floors	40
Garage floors	50
Exterior balconies, decks, porches	40
Ceilings (with storage)	20
Ceilings (without storage)	5

2. Snow loads. Roofs shall be designed and constructed to support the minimum snow loads listed on the zone map. The loads shall be assumed to act vertically over the roof area projected upon a horizontal plane.

(c) *Wind loads.* Dwellings shall be designed and constructed to withstand a horizontal and uplift pressure of 20 pounds per square foot acting over the surface area.

(d) *Fasteners.* All building components shall be fastened to withstand the dead load, live load and wind load.

Note: See the Appendix for a schedule of fasteners that will be acceptable to the department for compliance with this subsection. Other fastening methods may be allowed if engineered under s. Comm 21.02 (3).

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

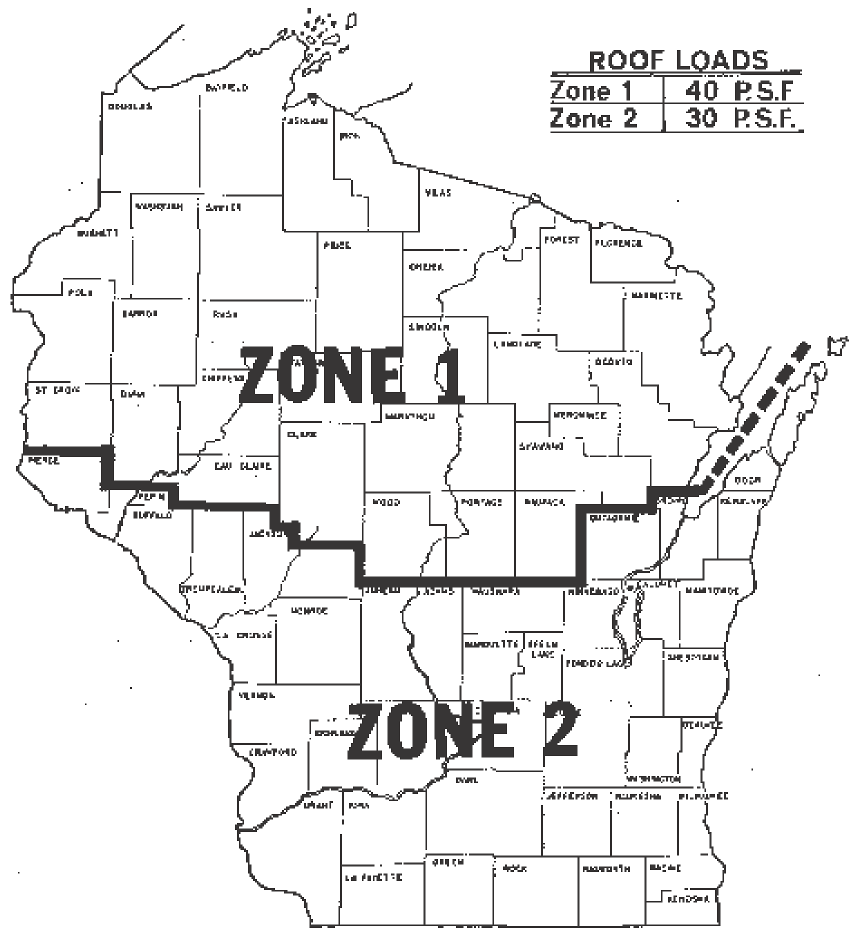
(2) METHODS OF DESIGN. All dwellings shall be designed by the method of structural analysis or the method of accepted practice specified in each part of this code.

Note: See ch. NR 116, rules of the department of natural resources, for special requirements relating to buildings located in flood plain zones. Information regarding the elevation of the regional flood may be obtained from the local zoning official.

(3) STRUCTURAL STANDARDS. (a) *General.* Design, construction, installation, practice and structural analysis shall conform to the following nationally recognized standards.

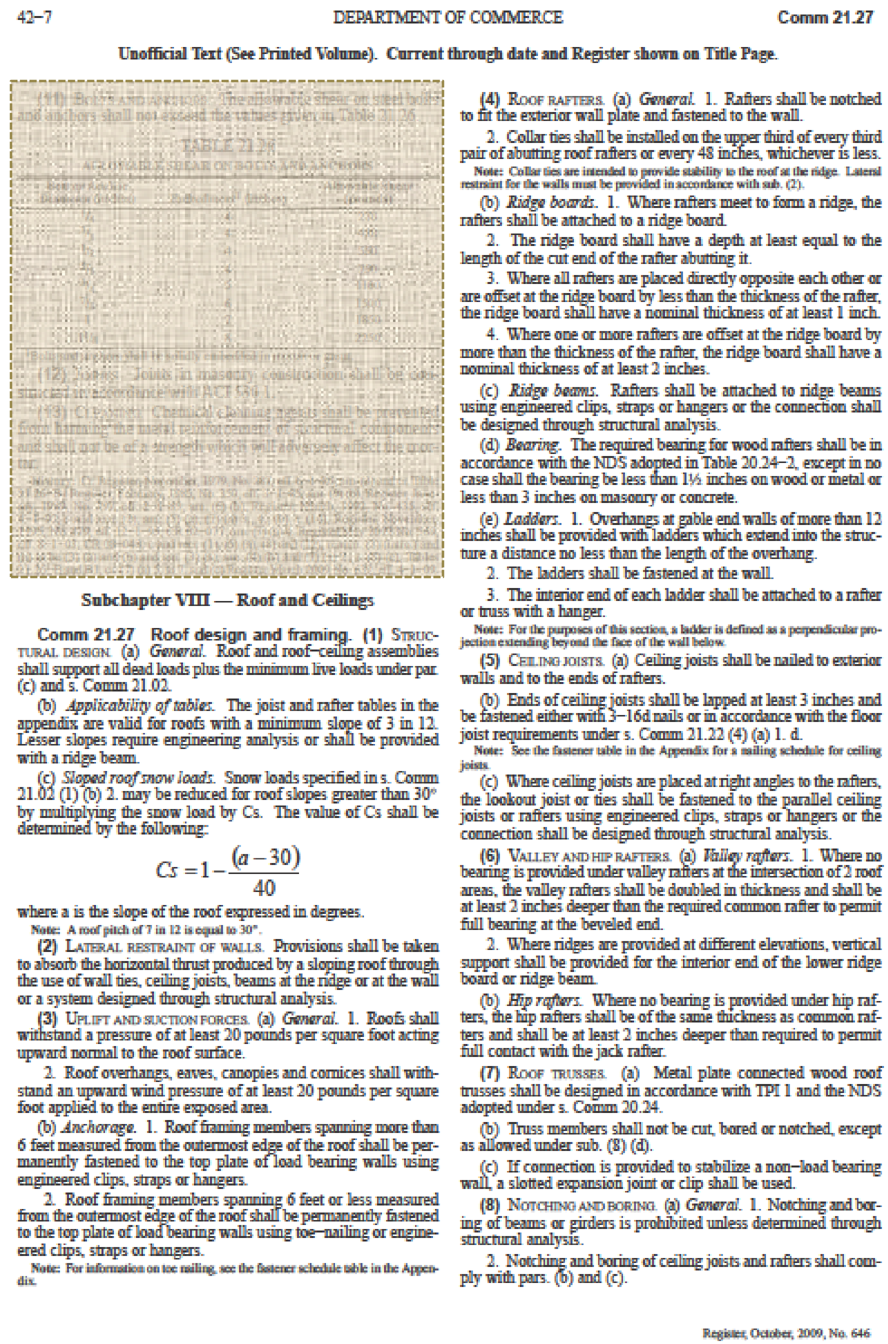
(b) *Wood.* 1. Except as provided in subd. 1. a. and b., structural lumber, glue–laminated timber, timber pilings and fastenings shall be designed in accordance with the "National Design Specification for Wood Construction" and the "Design Values for Wood Construction," a supplement to the National Design Specification for Wood Construction.

Figure 21.02
ZONE MAP FOR ROOF LOADS



Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

- Snow load reduction for roof slope
- Review all of the Code, it can only help



42–7 DEPARTMENT OF COMMERCE Comm 21.27

Unofficial Text (See Printed Volume). Current through date and Register shown on Title Page.

Subchapter VIII — Roof and Ceilings

Comm 21.27 Roof design and framing. (1) STRUCTURAL DESIGN. (a) *General.* Roof and roof–ceiling assemblies shall support all dead loads plus the minimum live loads under par. (c) and s. Comm 21.02.

(b) *Applicability of tables.* The joist and rafter tables in the appendix are valid for roofs with a minimum slope of 3 in 12. Lesser slopes require engineering analysis or shall be provided with a ridge beam.

(c) *Sloped roof snow loads.* Snow loads specified in s. Comm 21.02 (1) (b) 2. may be reduced for roof slopes greater than 30° by multiplying the snow load by Cs. The value of Cs shall be determined by the following:

$$Cs = 1 - \frac{(a - 30)}{40}$$

where a is the slope of the roof expressed in degrees.

Note: A roof pitch of 7 in 12 is equal to 30°.

(2) LATERAL RESTRAINT OF WALLS. Provisions shall be taken to absorb the horizontal thrust produced by a sloping roof through the use of wall ties, ceiling joists, beams at the ridge or at the wall or a system designed through structural analysis.

(3) UPLIFT AND SUCTION FORCES. (a) *General.* 1. Roofs shall withstand a pressure of at least 20 pounds per square foot acting upward normal to the roof surface.

2. Roof overhangs, eaves, canopies and cornices shall withstand an upward wind pressure of at least 20 pounds per square foot applied to the entire exposed area.

(b) *Anchorage.* 1. Roof framing members spanning more than 6 feet measured from the outermost edge of the roof shall be permanently fastened to the top plate of load bearing walls using engineered clips, straps or hangers.

2. Roof framing members spanning 6 feet or less measured from the outermost edge of the roof shall be permanently fastened to the top plate of load bearing walls using toe–nailing or engineered clips, straps or hangers.

Note: For information on toe nailing, see the fastener schedule table in the Appendix.

(4) ROOF RAFTERS. (a) *General.* 1. Rafters shall be notched to fit the exterior wall plate and fastened to the wall.

2. Collar ties shall be installed on the upper third of every third pair of abutting roof rafters or every 48 inches, whichever is less.

Note: Collar ties are intended to provide stability to the roof at the ridge. Lateral restraint for the walls must be provided in accordance with sub. (2).

(b) *Ridge boards.* 1. Where rafters meet to form a ridge, the rafters shall be attached to a ridge board.

2. The ridge board shall have a depth at least equal to the length of the cut end of the rafter abutting it.

3. Where all rafters are placed directly opposite each other or are offset at the ridge board by less than the thickness of the rafter, the ridge board shall have a nominal thickness of at least 1 inch.

4. Where one or more rafters are offset at the ridge board by more than the thickness of the rafter, the ridge board shall have a nominal thickness of at least 2 inches.

(c) *Ridge beams.* Rafters shall be attached to ridge beams using engineered clips, straps or hangers or the connection shall be designed through structural analysis.

(d) *Bearing.* The required bearing for wood rafters shall be in accordance with the NDS adopted in Table 20.24–2, except in no case shall the bearing be less than 1½ inches on wood or metal or less than 3 inches on masonry or concrete.

(e) *Ladders.* 1. Overhangs at gable end walls of more than 12 inches shall be provided with ladders which extend into the structure a distance no less than the length of the overhang.

2. The ladders shall be fastened at the wall.

3. The interior end of each ladder shall be attached to a rafter or truss with a hanger.

Note: For the purposes of this section, a ladder is defined as a perpendicular projection extending beyond the face of the wall below.

(5) CEILING JOISTS. (a) Ceiling joists shall be nailed to exterior walls and to the ends of rafters.

(b) Ends of ceiling joists shall be lapped at least 3 inches and be fastened either with 3–16d nails or in accordance with the floor joist requirements under s. Comm 21.22 (4) (a) 1. d.

Note: See the fastener table in the Appendix for a nailing schedule for ceiling joists.

(c) Where ceiling joists are placed at right angles to the rafters, the lookout joist or ties shall be fastened to the parallel ceiling joists or rafters using engineered clips, straps or hangers or the connection shall be designed through structural analysis.

(6) VALLEY AND HIP RAFTERS. (a) *Valley rafters.* 1. Where no bearing is provided under valley rafters at the intersection of 2 roof areas, the valley rafters shall be doubled in thickness and shall be at least 2 inches deeper than the required common rafter to permit full bearing at the beveled end.

2. Where ridges are provided at different elevations, vertical support shall be provided for the interior end of the lower ridge board or ridge beam.

(b) *Hip rafters.* Where no bearing is provided under hip rafters, the hip rafters shall be of the same thickness as common rafters and shall be at least 2 inches deeper than required to permit full contact with the jack rafter.

(7) ROOF TRUSSES. (a) Metal plate connected wood roof trusses shall be designed in accordance with TPI 1 and the NDS adopted under s. Comm 20.24.

(b) Truss members shall not be cut, bored or notched, except as allowed under sub. (8) (d).

(c) If connection is provided to stabilize a non–load bearing wall, a slotted expansion joint or clip shall be used.

(8) NOTCHING AND BORING. (a) *General.* 1. Notching and boring of beams or girders is prohibited unless determined through structural analysis.

2. Notching and boring of ceiling joists and rafters shall comply with pars. (b) and (c).

Register, October, 2009, No. 646

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

(b) *Notching.* 1. Notches located in the top or bottom of ceiling joists and rafters are prohibited from all of the following:

a. Having a depth exceeding $^1/_6$ the depth of the member.

b. Having a length exceeding $^1/_3$ the depth of the member.

c. Being located in the middle $^1/_3$ of the span of the member.

2. Where ceiling joists or rafters are notched at the ends, the notch may not exceed ¼ the depth of the member.

3. Bird mouth cuts may not exceed $^1/_3$ the depth of the rafter unless the seat cut bears fully on the wall plate.

(c) *Boring.* 1. Holes bored within 2 inches of the top or bottom of ceiling joists or rafters may not be located in the middle $^1/_3$ of the span of the member.

2. The diameter of a hole may not exceed $^1/_3$ the depth of the member.

3. A hole may not be bored within 2 inches of a notch or another hole.

4. The distance between adjacent holes may not be less than the diameter of the larger hole.

(d) *Engineered wood products.* Notching or boring of engineered wood products shall be done in accordance with the manufacturer's instructions provided those instructions were developed through structural analysis or product testing.

(9) ROOF SHEATHING, BOARDS AND PLANKING. (a) *Structural sheathing.* The allowable loads and spans for structural sheathing shall be in accordance with the grade stamp on the panel.

(b) *Roof boards.* 1. Where the rafter spacing is 24 inches on center or less, roof boards may be used that have a minimum thickness of $^5/_8$–inch for solid sheathing and $^3/_4$–inch for spaced sheathing.

2. Where the rafter spacing is greater than 24 inches on center, roof boards shall be tongue and groove, at least 1.5 inches thick.

(c) *Roof planks.* 1. Roof planks shall be tongue and groove or splined and at least 2 inches, nominal, in thickness.

2. Planks shall terminate over beams unless the joints are end matched.

3. The planks shall be laid so that no continuous line of joints will occur except at points of support.

4. Planks shall be nailed or fastened to each beam.

History: Cr. Register, November, 1979, No. 287, eff. 6–1–80; am (3) (a), Register, January, 1989, No. 397, eff. 2–1–89; r. and recr. (1), am. (3) (a), Register, March, 1992, No. 435, eff. 4–1–92; r. and recr. (3) (a), Register, November, 1995, No. 479, eff. 12–1–95; r. and recr. (3) (a) 1. and 2. c., Register, January, 1999, No. 517, eff. 2–1–99; am. (3) (a) 1. a., Register, March, 2001, No. 543, eff. 4–1–01; CR 02–077: r. and recr. (3) (b) Register May 2003 No. 569, eff. 8–1–03; CR 08–043: r. and recr. Register March 2009 No. 639, eff. 4–1–09.

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

- Note limitations of table
- Snow load reduction

Unofficial Text (See Printed Volume). Current through date and Register shown on Title Page.

UDC Floor & Ceiling Joist and Roof Rafter Span Tables and Design Value Tables

Use the following Span Tables to determine the maximum spans for floor and ceiling joists and roof rafters. These spans are based on:

- Simple, single spans (although the tables may be safely used for continuous two–span floor joists)
- Uniformly distributed loads
- Fully supported members with one edge properly sheathed and nailed
- For floor joists and roof rafters, the top edge shall be properly sheathed and nailed
- Rafters with a minimum 3:12 slope

The criteria for each Span Table is given in the upper left hand corner and is also summarized in the table of Span Tables below. Choose the appropriate Span Table based on the member type and required loading. Select your desired member depth, member spacing and span to determine the minimum Fb value. Note that these tables include recommended deflection criteria. However, for strict code compliance, only the Fb strength requirements must be satisfied. The modulus of elasticity (E) values, would be met for serviceability purposes only.

Note that straight–line interpolation is permitted for intermediate spans and design values. Span is measured from face to face of supports plus one–half of the required bearing of 1.5″ on wood or metal and 3″ on masonry or concrete at each end. For sloping rafters, the span is measured along the horizontal projection.

Section Comm 21.27 allows reduction of the snow live load for roof slopes greater than 30 degrees (7/12 slope) based on the formula Cs = 1 − (a−30)/40, where "a" is the slope of the roof expressed in degrees. Following is a table of tabulated values for certain roof slopes.

Slope	Angle in Degrees	Zone 1 Live Load (psf)	Zone 2 Live Load (psf)
7/12	30	40	30
10/12	40	30	22.5
12/12	45	25	18.8
14/12	50	20	15

Use the Design Value tables following the Span Tables to determine the acceptable species and grades to satisfy minimum Fb values obtained from the Span Tables. The Design Value tables assume at least three members spaced no more than 24″ on center. Use the Normal Duration column Fb values for joists and the Snow Loading column Fb values for rafters.

See the following examples for further guidance.

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

How to choose a table:

1) Rafter or Floor

2) Loads

3) Ceiling covering and deflection requirements

4) Roofing weight

- “Light” roofing < 10 psf

Tables are reprinted courtesy of American Forest & Paper Association.

Table No.	Member Type	Live Load (psf)	Dead Load (psf)	Condition	(Deflection)*
F–2	Floor Joists	40	10	–	L/360
C–1	Ceiling Joists	10	5	Drywall ceiling, no attic storage	L/240
C–2	Ceiling Joists	20	10	Attic storage	L/240
R–2	Roof Rafters	30 (Zone 2)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/240
R–3	Roof Rafters	40 (Zone 1)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/240
R–10	Roof Rafters	30 (Zone 2)	20	Heavy roof covering (clay tile)	L/240
R–11	Roof Rafters	40 (Zone 1)	20	Heavy roof covering (clay tile)	L/240
R–14	Roof Rafters	30 (Zone 2)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/180
R–15	Roof Rafters	40 (Zone 1)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/180
R–22	Roof Rafters	30 (Zone 2)	20	Heavy roof covering (clay tile)	L/180
R–23	Roof Rafters	40 (Zone 1)	20	Heavy roof covering (clay tile)	L/180

*Deflection criteria are optional. For roof rafters with drywall on the underside, use the stricter L/240 tables to limit deflection.

Example 1. Floor Joists. Assume a required single span of 12′–9″, dead load of 10 psf and joists spaced 16″ on center. Table F–2 (see following highlighted tables) shows that one solution is a grade of 2x8 having an Fb value of 1255 would allow a span of 12′–10″ which satisfies the condition. (Note that the recommended E value to limit deflection would be 1,600,000.) Going to the Design Value Tables, we find that as an example, 2x8 Hem Fir grade No.1 has an Fb value of 1310 for normal duration. (It also has an E value of 1,500,000 which does not satisfy the recommended deflection criteria.)

Example 2. Rafters. Assume a horizontal projected span of 13′–0″, a live load of 40 psf, dead load of 10 psf, a roof slope of 4/12 and rafters spaced 16″ on center. Since the slope is shallower than 7/12, there is no allowable reduction of the snow live load. Table R–3 shows that a 2x8 having an Fb value of 1300 would allow a span of 13′–1″ which satisfies the condition. (Note that the recommended E value to limit deflection would be 1,120,000.) Going to the Design Value Tables, we find that as an example, 2x8 Douglas Fir–Larch grade No.2 has an Fb value of 1390 for snow loading. (It also has an E value of 1,600,000 which satisfies the recommended deflection criteria.)

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

TABLE R–14
RAFTERS WITH L/180 DEFLECTION LIMITATION

- Use Table R-14 – 30 psf LL 10 psf DL
- 2 x 6 @ 16” o.c. 10’-0” span
- Fb = 1100 psi   E = 0.69 x 1,000,000=690,000 psi

DESIGN CRITERIA:
Strength – Live Load of 30 psf plus
Dead Load of 10 psf determines the required bending design value.
Deflection – For 30 psf live load.
Limited to span in inches divided by 180.

Rafter Bending Design Value, F_b, (psi)

Size (in)	Spacing (in)	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2x4	12.0	3–2	3–11	4–6	5–1	5–6	6–0	6–5	6–9	7–2	7–6	7–10	8–2	8–5	8–9
	16.0	2–9	3–5	3–11	4–4	4–10	5–2	5–6	5–10	6–2	6–6	6–9	7–1	7–4	7–7
	19.2	[illegible]	3–1	3–7	4–0	4–4	4–9	5–1	5–4	5–8	5–11	6–2	6–5	6–8	6–11
	24.0	[illegible]	2–9	3–2	3–7	3–11	4–3	4–6	4–10	5–1	5–4	5–6	5–9	6–0	6–2
2x6	12.0	5–0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11–9	12–4	12–10	13–3	13–9
	16.0	4–4	5–4	6–2	6–10	7–6	8–2	8–8	9–3	9–9	10–2	10–8	11–1	11–6	11–11
	19.2	4–0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9–9	10–1	10–6	10–10
	24.0	3–7	4–4	5–0	5–7	6–2	6–8	7–1	7–6	7–11	8–4	8–8	9–1	9–5	9–9
2x8	12.0	6–7	8–1	9–4	10–6	11–6	12–5	13–3	14–0	14–10	15–6	16–3	16–10	17–6	18–1
	16.0	5–9	7–0	8–1	9–1	9–11	10–9	11–6	12–2	12–10	13–5	14–0	14–7	15–2	15–8
	19.2	5–3	6–5	7–5	8–3	9–1	9–9	10–6	11–1	11–8	12–3	12–10	13–4	13–10	14–4
	24.0	4–8	5–9	6–7	7–5	8–1	8–9	9–4	9–11	10–6	11–0	11–6	11–11	12–5	12–10
2x10	12.0	8–5	10–4	11–11	13–4	14–8	15–10	16–11	17–11	18–11	19–10	20–8	21–6	22–4	23–1
	16.0	7–4	8–11	10–4	11–7	12–8	13–8	14–8	15–6	16–4	17–2	17–11	18–8	19–4	20–0
	19.2	6–8	8–2	9–5	10–7	11–7	12–6	13–4	14–2	14–11	15–8	16–4	17–0	17–8	18–3
	24.0	6–0	7–4	8–5	9–5	10–4	11–2	11–11	12–8	13–4	14–0	14–8	15–3	15–10	16–4
E	12.0	0.06	0.11	0.17	0.24	0.32	0.40	0.49	0.59	0.69	0.79	0.91	1.02	1.14	1.27
E	16.0	0.05	0.10	0.15	0.21	0.28	0.35	0.43	0.51	0.60	0.69	0.78	0.88	0.99	1.10
E	19.2	0.05	0.09	0.14	0.19	0.25	0.32	0.39	0.47	0.54	0.63	0.72	0.81	0.90	1.00
E	24.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.56	0.64	0.72	0.81	0.89

Size (in)	Spacing (in)	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2x4	12.0	9–0	9–4	9–7	9–10	10–1	10–4	10–7	10–10	11–1						
	16.0	7–10	8–1	8–4	8–6	8–9	9–0	9–2	9–5	9–7	9–9	10–0				
	19.2	7–2	7–4	7–7	7–9	8–0	8–2	8–5	8–7	8–9	8–11	9–1	9–3	9–5		
	24.0	6–5	6–7	6–9	7–0	7–2	7–4	7–6	7–8	7–10	8–0	8–2	8–4	8–5	8–7	8–9
2x6	12.0	14–2	14–8	15–1	15–6	15–11	16–3	16–8	17–0	17–5						
	16.0	12–4	12–8	13–1	13–5	13–9	14–1	14–5	14–9	15–1	15–4	15–8				
	19.2	11–3	11–7	11–11	12–3	12–7	12–10	13–2	13–6	13–9	14–0	14–4	14–7	14–10		
	24.0	10–0	10–4	10–8	10–11	11–3	11–6	11–9	12–0	12–4	12–7	12–10	13–1	13–3	13–6	13–9
2x8	12.0	18–9	19–4	19–10	20–5	20–11	21–5	21–11	22–5	22–11						
	16.0	16–3	16–9	17–2	17–8	18–1	18–7	19–0	19–5	19–10	20–3	20–8				
	19.2	14–10	15–3	15–8	16–2	16–7	16–11	17–4	17–9	18–1	18–6	18–10	19–3	19–7		
	24.0	13–3	13–8	14–0	14–5	14–10	15–2	15–6	15–10	16–3	16–7	16–10	17–2	17–6	17–10	18–1
2x10	12.0	23–11	24–7	25–4	26–0											
	16.0	20–8	21–4	21–11	22–6	23–1	23–8	24–3	24–10	25–4	25–10					
	19.2	18–11	19–6	20–0	20–7	21–1	21–8	22–2	22–8	23–1	23–7	24–1	24–6	25–0		
	24.0	16–11	17–5	17–11	18–5	18–11	19–4	19–10	20–3	20–8	21–1	21–6	21–11	22–4	22–9	23–1
E	12.0	1.39	1.53	1.66	1.80	1.95	2.10	2.25	2.40	2.56						
E	16.0	1.21	1.32	1.44	1.56	1.69	1.82	1.95	2.08	2.22	2.36	2.50				
E	19.2	1.10	1.21	1.32	1.43	1.54	1.66	1.78	1.90	2.03	2.15	2.28	2.42	2.55		
E	24.0	0.99	1.08	1.18	1.28	1.38	1.48	1.59	1.70	1.81	1.93	2.04	2.16	2.28	2.41	2.53

Note: The required modulus of elasticity, E, in 1,000,000 pounds per square inch is shown at the bottom of each table, is limited to 2.6 million psi and less, and is applicable to all lumber sizes shown. Spans are shown in feet–inches and are limited to 26′ and less. Check sources of supply for availability of lumber in lengths greater than 20′.

- Locate member size, spacing and span
- Follow up to Fb_{min} and down to E_{min}

Uniform Dwelling Code of the Wisconsin Administrative Code (UDC)

- Note range in values
- Unless the lumber is stamped with grade and species, use SPF (South) and verify No. 2 grade per the following information

Species and Grade	Size	Design Value in Bending, "Fb" Normal Duration	Design Value in Bending, "Fb" Snow Loading	Modulus of Elasticity "E"	Grading Rules Agency
Douglas Fir–Larch (North)					
Select Structural		2245	2580	1,900,000	
No.1 /No.2		1425	1635	1,600,000	
No.3		820	940	1,400,000	
Stud	2x4	820	945	1,400,000	
Construction		1095	1255	1,500,000	
Standard		605	695	1,400,000	
Utility		290	330	1,300,000	
Select Structural		1945	2235	1,900,000	
No.1 /No.2	2x6	1235	1420	1,600,000	
No.3		710	815	1,400,000	
Stud		750	860	1,400,000	NLGA
Select Structural		1795	2065	1,900,000	
No.1 /No.2	2x8	1140	1310	1,600,000	
No.3		655	755	1,400,000	
Select Structural		1645	1890	1,900,000	
No.1 /No–2	2x10	1045	1200	1,600,000	
No.3		600	690	1,400,000	
Select Structural		1495	1720	1,900,000	
No.1 /No.2	2x12	950	1090	1,600,000	
No.3		545	630	1,400,000	
Douglas Fir–South					
Select Structural		2245	2580	1,400,000	
No.1		1555	1785	1,300,000	
No.2		1425	1635	1,200,000	
No.3	2x4	820	940	1,100,000	
Stud		820	945	1,100,000	
Construction		1065	1225	1,200,000	
Standard		605	695	1,100,000	
Utility		290	330	1,000,000	
Select Structural		1945	2235	1,400,000	
No.1		1345	1545	1,300,000	
No.2	2x6	1235	1420	1,200,000	
No.3		710	815	1,100,000	
Stud		750	860	1,100,000	WWPA
Select Structural		1795	2065	1,400,000	
No.1	2x8	1240	1430	1,300,000	
No.2		1140	1310	1,200,000	
No.3		655	755	1,100,000	
Select Structural		1645	1890	1,400,000	
No.1	2x10	1140	1310	1,300,000	
No.2		1045	1200	1,200,000	
No.3		600	690	1,100,000	
Select Structural		1495	1720	1,400,000	
No.1	2x12	1035	1190	1,300,000	
No.2		950	1090	1,200,000	
No.3		545	630	1,100,000	

Methods for Evaluating a Structure

Simplified method (compare new to existing):

- Determine original design loads of an existing structure and verify conformance to the current building code
- Determine and account for changes to roof loads due to the installation of solar equipment
  - Live loads
  - Snow loads
  - Dead loads
  - Other loads per building code
- Make comparison between the structure as originally designed and the structure after the solar equipment has been installed.

More detailed method of evaluation:

- Perform complete structural analysis and review of all structural elements affected by the installation and make a determination as to their adequacy
  - Includes the analysis of members, their connections, bearing condition, and stability,
  - Follows loads through the foundations
  - Used when the simplified method cannot be performed, is not conclusive, or yields unfavorable results and reinforcing the structure is not easily accomplished.
  - Removes any doubt of adequacy and grey areas
  - Usually performed by a Structural Engineer.

Only the simplified method is included in this presentation

Information required for evaluation

Original building construction documents or as-built drawings noting:

- Roof construction
  - Rafter size, species, grade, span, and spacing
  - Truss design literature
  - Roof sheathing thickness and type
  - Roofing material and composition
  - Ceiling location and composition
- Any other elements affected by installation
  - Typical elements include walls, headers, beams, and foundations.
- Missing or incomplete data requires the designer/reviewer to take a conservative approach and could delay permitting process

Solar equipment specifications and layout including:

- Weights of all equipment and their distribution
- Locations of all equipment and supports

Current and applicable code and standards

- Uniform Dwelling Code of the Wisconsin Administrative Code
- Additional design references as applicable

Roof Construction

TRUSSES

Structural elements consisting of multiple members orientated in triangular patterns

Original truss design documents, created by the manufacturer, are needed to utilize the simplified method of evaluation.

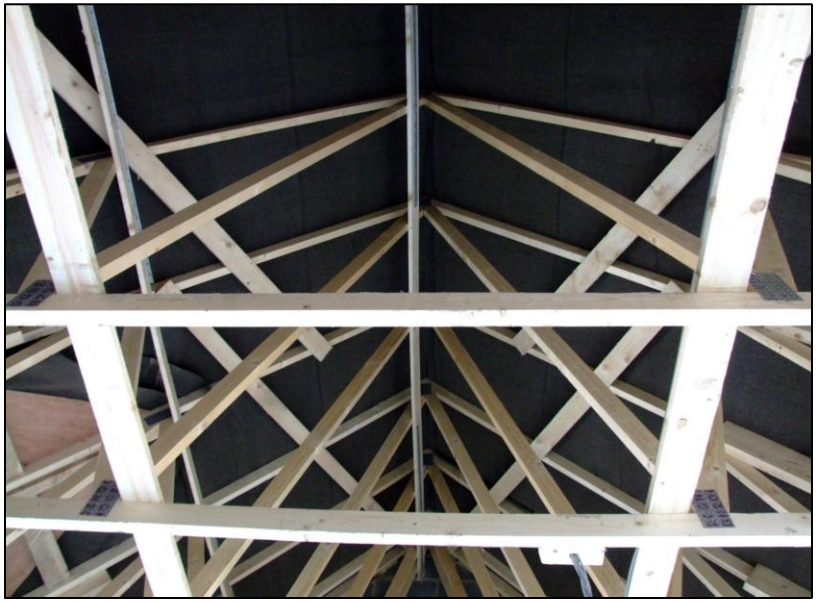
RAFTERS

With room within attic space

- Can be complicated and are outside the scope of this presentation.

Without room in attic space

- Simple spans that can be evaluated with the use of UDC



Index of Examples

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

1. Check adherence to current building code

    a. Tabulate dead loads
    b. DL<10 psf or 10<DL<20 psf
    c. Check UDC tables

2. Tabulate new loads

    a. Solar panel weight
    b. Removal of roofing

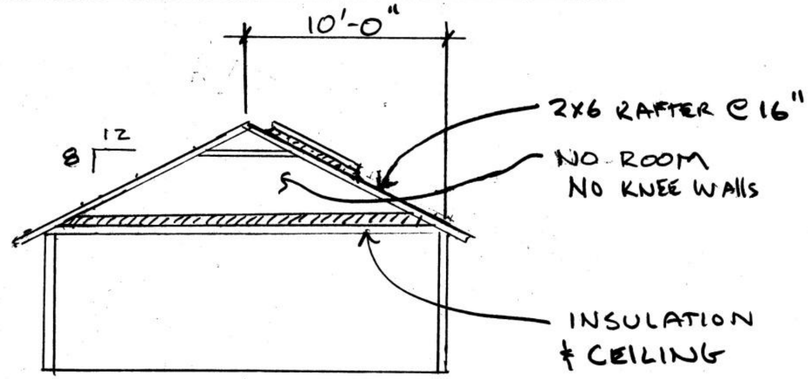
3. Make comparison & judgment

(Creating moment and shear diagrams may be helpful if member capacity is borderline)

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- Panels consist of (3) 72”x54” 141lb SHW bearing directly on roof sheathing.
- Roofing material is removed at panel
- Panel sits directly on roof sheathing and is supported on all sides
- Flashing is installed around panels

EXISTING ROOF RAFTERS CHECK



FROM UDC TABLES

ZONE 2 SLOPE of 8:12

SHINGLE ROOF

NO CEILING OR INSULATION ATTACHED TO RAFTER

NO. 2 LUMBER GRADE OR BETTER

USE TABLE R-14 30 PSF LL, 10 PSF DL

2x6 @ 16" o.c. 10'-0" SPAN

F_b = 1100 psi E = 0.69 x 1,000,000

= 690,000 psi

FROM SPECIES & GRADE TABLES

DF (NORTH) F_b = 1420 (SNOW) OK E = 1,600,000 OK

SPF (SOUTH) F_b = 1190 (SNOW) OK E = 1,100,000 OK

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

(2) METHODS OF DESIGN. All dwellings shall be designed by the method of structural analysis or the method of accepted practice specified in each part of this code.

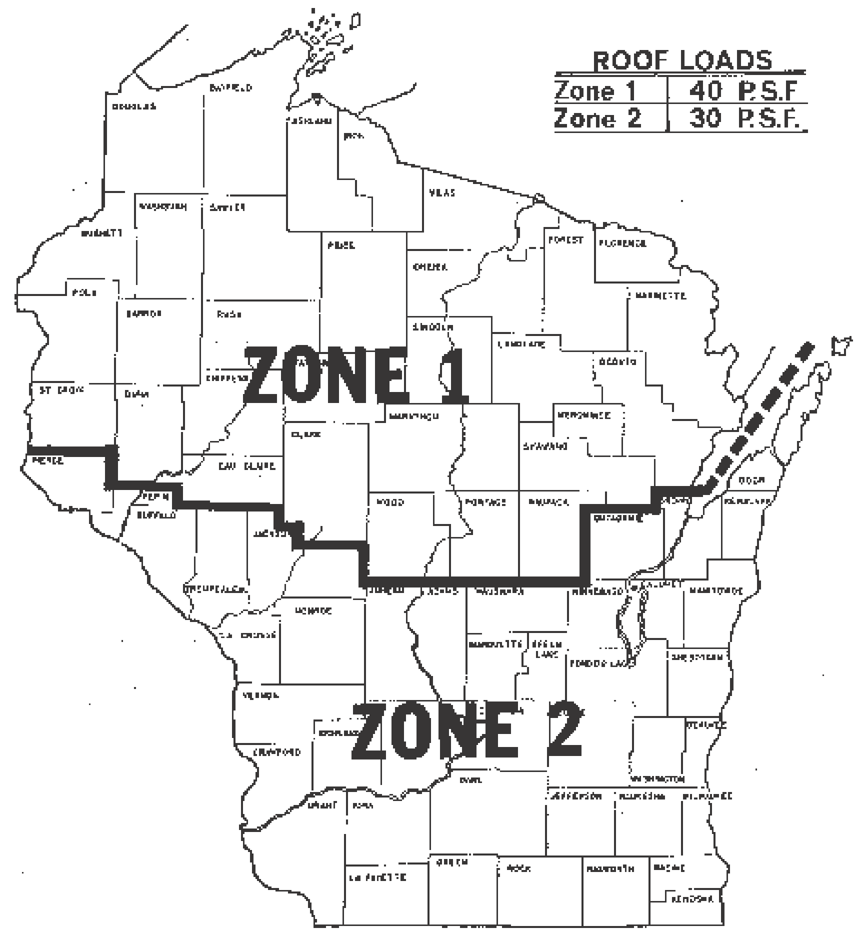
Note: See ch. NR 116, rules of the department of natural resources, for special requirements relating to buildings located in flood plain zones. Information regarding the elevation of the regional flood may be obtained from the local zoning official.

(3) STRUCTURAL STANDARDS. (a) *General.* Design, construction, installation, practice and structural analysis shall conform to the following nationally recognized standards.

(b) *Wood.* 1. Except as provided in subd. 1. a. and b., structural lumber, glue–laminated timber, timber pilings and fastenings shall be designed in accordance with the "National Design Specification for Wood Construction" and the "Design Values for Wood Construction," a supplement to the National Design Specification for Wood Construction.

Figure 21.02

ZONE MAP FOR ROOF LOADS



Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- Rafter
- Zone 2 = 30 psf
- No ceiling thus L/180 defection requirement
- “Light” roofing < 10 psf
- Table R-14

Unofficial Text (See Printed Volume). Current through date and Register shown on Title Page.

Tables are reprinted courtesy of American Forest & Paper Association.

Table No.	Member Type	Live Load (psf)	Dead Load (psf)	Condition	(Deflection)*
F–2	Floor Joists	40	10	–	L/360
C–1	Ceiling Joists	10	5	Drywall ceiling, no attic storage	L/240
C–2	Ceiling Joists	20	10	Attic storage	L/240
R–2	Roof Rafters	30 (Zone 2)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/240
R–3	Roof Rafters	40 (Zone 1)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/240
R–10	Roof Rafters	30 (Zone 2)	20	Heavy roof covering (clay tile)	L/240
R–11	Roof Rafters	40 (Zone 1)	20	Heavy roof covering (clay tile)	L/240
R–14	Roof Rafters	30 (Zone 2)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/180
R–15	Roof Rafters	40 (Zone 1)	10	Maximum 2 layers of asphalt shingles or wood shakes/shingles	L/180
R–22	Roof Rafters	30 (Zone 2)	20	Heavy roof covering (clay tile)	L/180
R–23	Roof Rafters	40 (Zone 1)	20	Heavy roof covering (clay tile)	L/180

*Deflection criteria are optional. For roof rafters with drywall on the underside, use the stricter L/240 tables to limit deflection.

Example 1. Floor Joists. Assume a required single span of 12′–9″, dead load of 10 psf and joists spaced 16″ on center. Table F–2 (see following highlighted tables) shows that one solution is a grade of 2x8 having an Fb value of 1255 would allow a span of 12′–10″ which satisfies the condition. (Note that the recommended E value to limit deflection would be 1,600,000.) Going to the Design Value Tables, we find that as an example, 2x8 Hem Fir grade No.1 has an Fb value of 1310 for normal duration. (It also has an E value of 1,500,000 which does not satisfy the recommended deflection criteria.)

Example 2. Rafters. Assume a horizontal projected span of 13′–0″, a live load of 40 psf, dead load of 10 psf, a roof slope of 4/12 and rafters spaced 16″ on center. Since the slope is shallower than 7/12, there is no allowable reduction of the snow live load. Table R–3 shows that a 2x8 having an Fb value of 1300 would allow a span of 13′–1″ which satisfies the condition. (Note that the recommended E value to limit deflection would be 1,120,000.) Going to the Design Value Tables, we find that as an example, 2x8 Douglas Fir–Larch grade No.2 has an Fb value of 1390 for snow loading. (It also has an E value of 1,600,000 which satisfies the recommended deflection criteria.)

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

TABLE R–14
RAFTERS WITH L/180 DEFLECTION LIMITATION

DESIGN CRITERIA:
Strength – Live Load of 30 psf plus
Dead Load of 10 psf determines the required bending design value.
Deflection – For 30 psf live load.
Limited to span in inches divided by 180.

- Use Table R-14 – 30 psf LL 10 psf DL
- 2 x 6 @ 16” o.c. 10’-0” span
- Fb = 1100 psi   E = 0.69 x 1,000,000=690,000 psi

Rafter Bending Design Value, F_b (psi)

Size (in)	Spacing (in)	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2x4	12.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1						
	16.0	2-9	3-5	3-11	4-4	4-10	5-2	5-6	[illegible]	[illegible]	6-6	[illegible]	[illegible]	7-4	7-7	7-10	8-1	8-4	8-6	8-9	9-0	9-2	9-5	9-7	9-9	10-0				
	19.2	[illegible]	3-1	3-7	4-0	4-4	4-9	5-1	5-4	5-8	5-11	6-2	6-5	6-8	6-11	7-2	7-4	7-7	7-9	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5		
	24.0	[illegible]	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
2x6	12.0	5-0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11-9	12-4	12-10	13-3	13-9	14-2	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5						
	16.0	4-4	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11	12-4	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8				
	19.2	4-0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9-9	10-1	10-6	10-10	11-3	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7	14-10		
	24.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
2x8	12.0	[illegible]	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11						
	16.0	5-9	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8	16-3	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8				
	19.2	5-3	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4	14-10	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3	19-7		
	24.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
2x10	12.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11	24-7	25-4	26-0											
	16.0	7-4	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0	20-8	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10					
	19.2	6-8	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3	18-11	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6	25-0		
	24.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
E	12.0	0.06	0.11	0.17	0.24	0.32	0.40	0.49	0.59	0.69	0.79	0.91	1.02	1.14	1.27	1.39	1.53	1.66	1.80	1.95	2.10	2.25	2.40	2.56						
E	16.0	0.05	0.10	0.15	0.21	0.28	0.35	0.43	0.51	0.60	0.69	0.78	0.88	0.99	1.10	1.21	1.32	1.44	1.56	1.69	1.82	1.95	2.08	2.22	2.36	2.50				
E	19.2	0.05	0.09	0.14	0.19	0.25	0.32	0.39	0.47	0.54	0.63	0.72	0.81	0.90	1.00	1.10	1.21	1.32	1.43	1.54	1.66	1.78	1.90	2.03	2.15	2.28	2.42	2.55		
E	24.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.56	0.64	0.72	0.81	0.89	0.99	1.08	1.18	1.28	1.38	1.48	1.59	1.70	1.81	1.93	2.04	2.16	2.28	2.41	2.53

Note: The required modulus of elasticity, E, in 1,000,000 pounds per square inch is shown at the bottom of each table, is limited to 2.6 million psi and less, and is applicable to all lumber sizes shown. Spans are shown in feet–inches and are limited to 26’ and less. Check sources of supply for availability of lumber in lengths greater than 20’.

- Locate member size, spacing and span

- Follow up to Fb_{min} and down to E_{min}

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- Note range in values

- Unless the lumber is stamped with grade and species, use SPF (South) and verify No. 2 grade per "Identifying #2 Structural Framing" (attached).

Unofficial Text (See Printed Volume). Current through date and Register shown on Title Page.

Species and Grade	Size	Design Value in Bending, "Fb"		Modulus of Elasticity "E"	Grading Rules Agency
		Normal Duration	Snow Loading		
Douglas Fir–Larch (North)					
Select Structural		2245	2580	1,900,000	
No.1 /No.2		1425	1635	1,600,000	
No.3		820	940	1,400,000	
Stud	2x4	820	945	1,400,000	
Construction		1095	1255	1,500,000	
Standard		605	695	1,400,000	
Utility		290	330	1,300,000	
Select Structural		1945	2235	1,900,000	
No.1 /No.2	2x6	1235	1420	1,600,000	
No.3		710	815	1,400,000	
Stud		750	860	1,400,000	NLGA
Select Structural		1795	2065	1,900,000	
No.1 /No.2	2x8	1140	1310	1,600,000	
No.3		655	755	1,400,000	
Select Structural		1645	1890	1,900,000	
No.1 /No–2	2x10	1045	1200	1,600,000	
No.3		600	690	1,400,000	
Select Structural		1495	1720	1,900,000	
No.1 /No.2	2x12	950	1090	1,600,000	
No.3		545	630	1,400,000	
Douglas Fir–South					
Select Structural		2245	2580	1,400,000	
No.1		1555	1785	1,300,000	
No.2		1425	1635	1,200,000	
No.3	2x4	820	940	1,100,000	
Stud		820	945	1,100,000	
Construction		1065	1225	1,200,000	
Standard		605	695	1,100,000	
Utility		290	330	1,000,000	
Select Structural		1945	2235	1,400,000	
No.1		1345	1545	1,300,000	
No.2	2x6	1235	1420	1,200,000	
No.3		710	815	1,100,000	
Stud		750	860	1,100,000	WWPA
Select Structural		1795	2065	1,400,000	
No.1	2x8	1240	1430	1,300,000	
No.2		1140	1310	1,200,000	
No.3		655	755	1,100,000	
Select Structural		1645	1890	1,400,000	
No.1	2x10	1140	1310	1,300,000	
No.2		1045	1200	1,200,000	
No.3		600	690	1,100,000	
Select Structural		1495	1720	1,400,000	
No.1	2x12	1035	1190	1,300,000	
No.2		950	1090	1,200,000	
No.3		545	630	1,100,000	

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- Weights of building materials should be calculated for each job based on a thorough examination of the building
- Exercise in unit conversion

* BUILDING MATERIAL WEIGHTS (DEAD LOAD)

SHINGLES — 3 TAB — 200# / 100FT^2 = 2 PSF

ARCH — 265# / 100FT^2 = 2.65 PSF

PLYWOOD — 0.40# PER 1/8" OF THICKNESS

$\frac{1}{2}" - 0.4 \times \frac{0.50}{0.125} = 1.6$ #/SQ FT

(0.45 - 0.50 #/$\frac{1}{8}$" FOR OSB)

RAFTERS (SOUTHERN PINE @ 36.4 PCF) (12% MOISTURE

(SPRUCE PINE FUR @ 28.7 PCF)
SPF

2x6 — $1\frac{1}{2}" \times 5\frac{1}{2}" = 8.25\ in^2$

$8.25\ in^2 \times \frac{1\ ft^2}{144\ in^2} \times 36.4\ \frac{Lb}{ft^3} = \underline{2.1}\ \frac{Lb}{ft}$

@ 24' o.c.

$2.1\ \frac{Lb}{ft} \times \frac{1\ RAFTER}{2\ ft} = \underline{1.05}\ \frac{Lb}{ft^2}$

@ 16" o.c

$2.1 \times \frac{1}{1.33'} = 1.6\ \frac{Lb}{ft^2}$

OTHER DEAD LOADS: INSULATION
GYPSUM BOARD
MECHANICAL EQUIPMENT
??

REFERENCE(S)

TIMBER CONSTRUCTION MANUAL 4th ADDITION — AMERICAN INSTITUTE OF TIMBER CONSTRUCTION

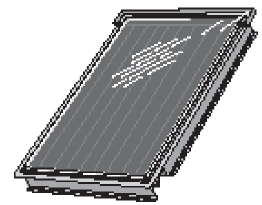
Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

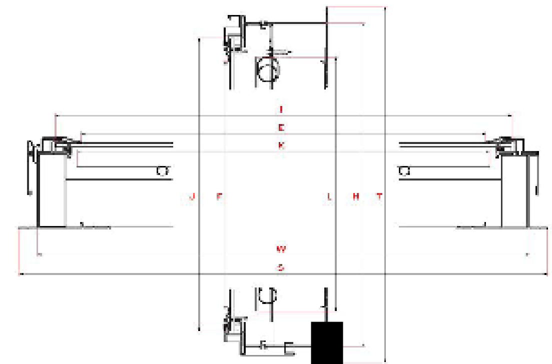
- Always provide manufacturer's product specification that include the product weights with the permit application

VELUX

Solar water heating

VELUX solar collector





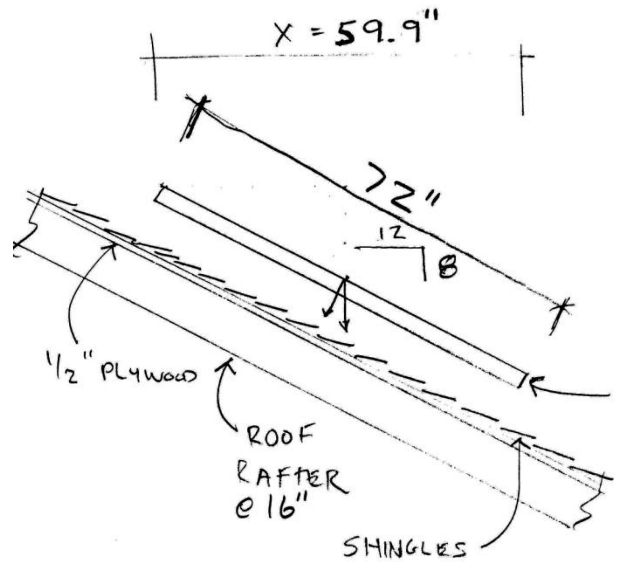
Measurements (inches)	Width				Height				Depth
	Code	U12	S06	M08	Code	U12	S06	M08	All
Gross	S	54.1	46.2	32.0	T	72.0	47.5	56.2	3.9
Frame	W	52.8	44.9	30.7	H	70.7	46.2	54.8	
Glass	I	51.5	43.6	29.4	J	69.4	44.9	53.5	
Aperture	E	49.5	41.6	27.4	F	67.4	42.9	51.6	
Absorber	K	49.8	41.9	27.8	L	67.7	43.2	51.9	

Technical specifications		CLR U12 4000	CLI U12 4000	CLI S06 4000	CLI M08 4000
Weight (lbs.)	Collector weight	130	130	73	57
	Weight w/fluid	$\boxed{141}$	141	79	64
Collector area (sq. ft.)	Gross area	27.1	27.1	15.2	12.5
	Aperture area	23.1	23.1	12.4	9.8
	Absorber area	23.4	23.4	12.6	10.0
Fluid volume (gal.)		0.58	0.58	0.34	0.24
Max operating pressure (psi)		87	87	87	87
Test pressure (psi)		145	145	145	145
Stagnation temperature (°F)		374	374	374	365
Thermal performance rating - warm climate (1000s btu/day)	Clear day	29	29	15	12
	Mildly cloudy day	20	20	11	8
	Cloudy day	11	11	6	5
Thermal performance rating - cool climate (1000s btu/day)	Clear day	19	19	10	8
	Mildly cloudy day	11	11	6	4
	Cloudy day	4	4	2	1
Efficiency	eta0 (start efficiency)	0.6960	0.6960	0.6610	0.6390
	a1 (Btu/hr*ft2**F)	0.4747	0.4747	0.4666	0.4603
	a2 (Btu/hr*ft2**F2)	0.0020	0.0020	0.0019	0.0018
Structural performance design pressure (DP)	Downward load (psf)	+70	+125	+200	+255
	Uplift load (psf)	-60	-70	-87.5	-55

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- As the panel is tilted upward, the lbs/sq ft applied to the horizontal projection of the roof increases even though the panel weight does not change

VERTICAL COMPONENT OF PANEL WEIGHT *
ON A SLOPE, 72"H x 54.1"W 141 Lb w/ FLUID



$$\frac{\sqrt{12^2+8^2}}{72''} = \frac{12}{X}$$

$$X = 59.9''$$

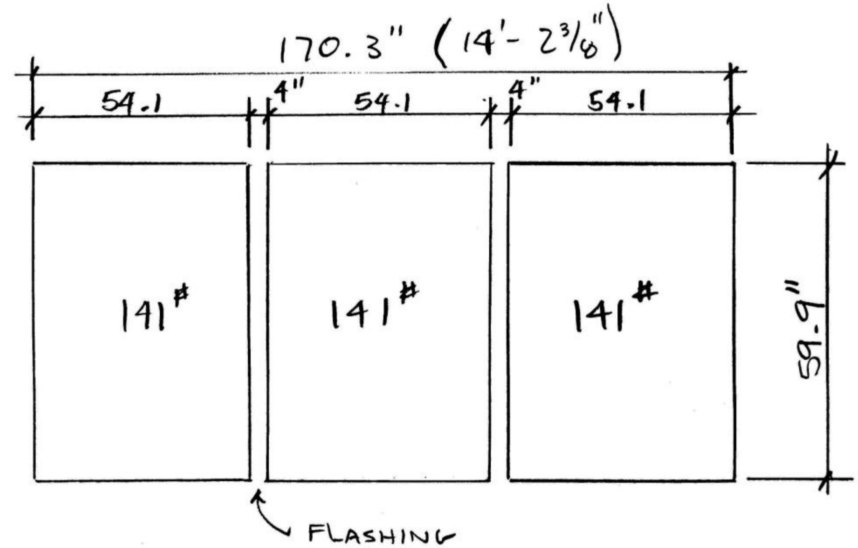
PANEL 72" x 54.1"
141 #

* BUILDING MATERIAL AND SOLAR PANEL WEIGHTS WILL VARY. THOUROUGHLY INVESTIGATE ROOF COMPOSITION.

Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- Determine area load of system (psf)
- Area is comprised of system dimensions

FLUSH MOUNT SOLAR HOT WATER
3 - PANELS



HORIZONTA PROJECTED PANEL WT.

$$\text{WEIGHT} = 141 \times 3 = 423^{\#}$$

$$\text{AREA} = 170.3'' \times 59.9'' = 10{,}201\ \text{in}^2$$

$$10201\ \text{in}^2 \div 144\ \frac{\text{in}^2}{\text{ft}^2} = 70.8\ \text{ft}^2$$

$$\text{DISTRIBUTED LOAD} = \frac{423^{\#}}{70.8\ \text{ft}^2} = 5.97\ {}^{\#}/_{\text{ft}^2}$$

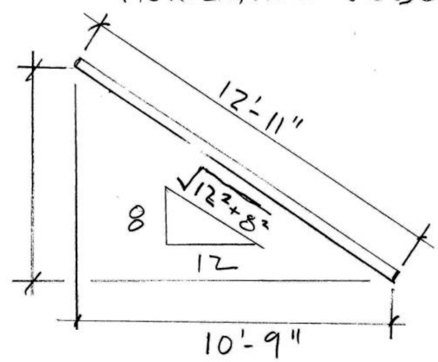
Example 1 – Flush Mounted Solar Hot Water Flashed Into Roofing – NO RAILS – Rafter Roof

- Already determined the live load requirement is satisfied
- Verify that the dead loads (“DL”) are not in excess of 10 psf
- If DL > 10 psf, further evaluation utilizing shear & moment calculation is needed

DEAD LOAD TABULATION

3 TAB SHINGLES	2.0 PSF PER LAYER
1/2" PLYWOOD	1.6 PSF
2X6 RAFTERS @ 16"	1.6 PSF
	5.2 PSF

HORIZONTAL PROJECTED DEAD LOAD



$\frac{5.2 \times \sqrt{12^2+8^2}}{12} = 6.25 \text{PSF}$

$\frac{5.2 \times 12.9167'}{10.75'} = 6.25 \text{PSF}$

ADDT. LAYER OF SHINGLES = 2.0 PSF

WITHOUT SHINGLES

DL = 6.25 - 2.4 = 3.85 PSF

DESIGN DEAD LOAD = 10 PSF PER UDC (HORIZONTAL)

ACTUAL DEAD LOADS, W PSF

@ TYPICAL ROOF (PSF)

W = 6.25 TO 8.65. < 10 PSF OK

@ FLASHED PANEL (NO SHINGLES)

W = 3.85 + 5.97 = 9.82 PSF < 10 PSF OK

Example 2 – Flush Mounted Solar Hot Water Flashed Into Roof – NO RAILS – Truss Roof

1. Determine original construction design loads

   a. Manufacturer supplied calculations
   b. Engineering analysis
   c. Original documents

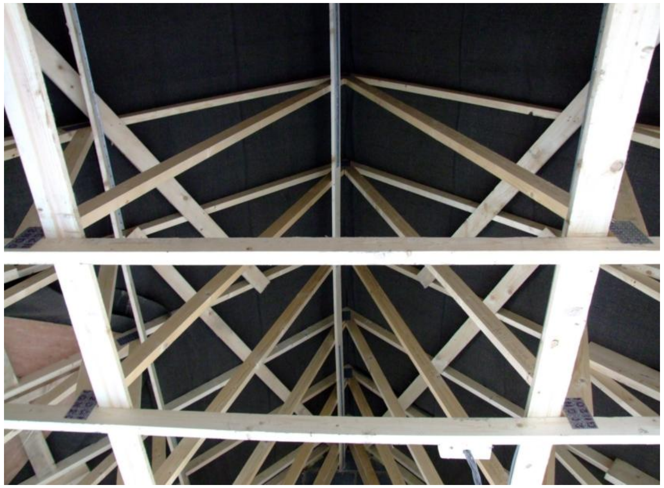
2. Tabulate new loads

   a. Solar panel weight
   b. Removal of roofing

3. Make comparison & judgment

<u>Same process as Example 1</u>

▲ Panels



Example 3 – Flush Mounted PV System on Rails – Rafter Roof

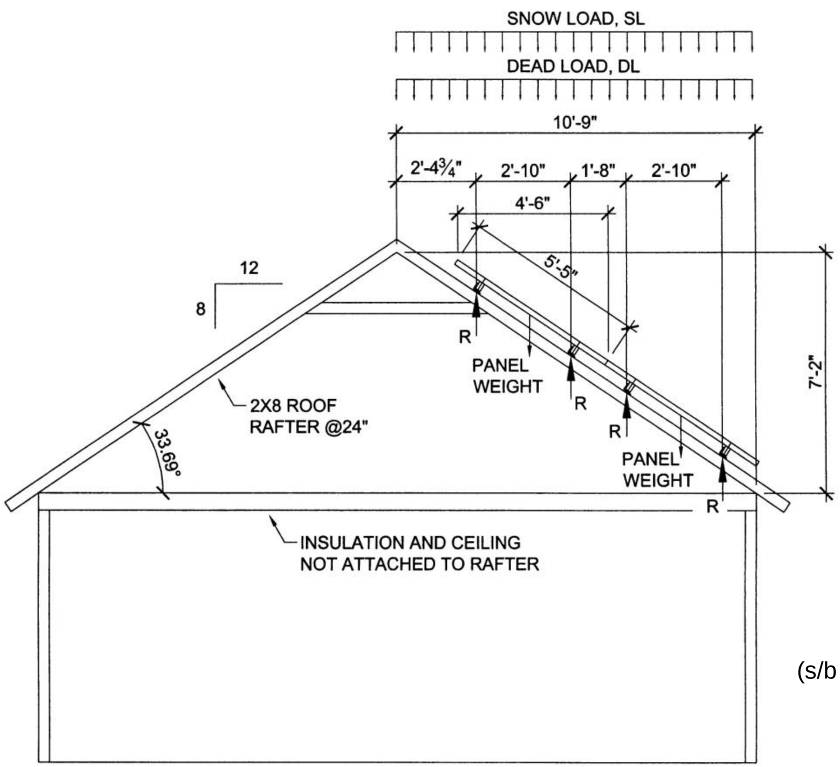
1. Check adequacy of existing rafter
2. Determine maximum allowable moment and shear (“M” and “V”) of existing member based on UDC tables (using span & loads from tables)
3. Determine new load amounts & configuration on each rafter
4. Calculate new moments & shear diagrams and compare to maximum allowable moment and shear.

If: $M_{new} < M_{allow}$ <u>OK</u>

$V_{new} < V_{allow}$ <u>OK</u>

If not: possibly add more supports or reinforce roof

Example 3 – Flush Mounted PV System on Rails – Rafter Roof



BUILDING SECTION

BUILDING CODE
UNIFORM DWELLING CODE OF THE
WISCONSIN ADMINISTRATIVE CODE

DESIGN LOADS:

SNOW LOAD:
ZONE 2 - 30PSF

SNOW LOAD SLOPE ADJUSTMENT:
COMM 21.27-1(c)

Cs=1-(a-30)/40

WHERE:
Cs=SNOW LOAD MULTIPLIER
a = ROOF SLOPE (PITCH OF 7-12 = 30DEG)

Cs = 1-(33.69-30)/40
Cs = 0.91

SNOW LOAD FROM MAP = 30PSF ZONE 2

REDUCED SNOW LOAD FOR SLOPE = 30x0.91=27.30psf

DEAD LOADS:	IN PLANE	HORIZONTAL PROJECTION
ROOFING (ARCH)	2.7psf	3.2psf
½" SHEATHING (OSB)	2.0 psf	2.4psf
(s/b 2x8) 2X6 RAFTER(2.1PLF/2FT O.C.)	1.05psf	1.3psf
TOTAL DEAD LOAD:	5.75psf	6.90psf

SOLAR PANEL LOADS:
4'-6" X 3'-4" = 15 SQ FT PROJECTED PANEL AREA

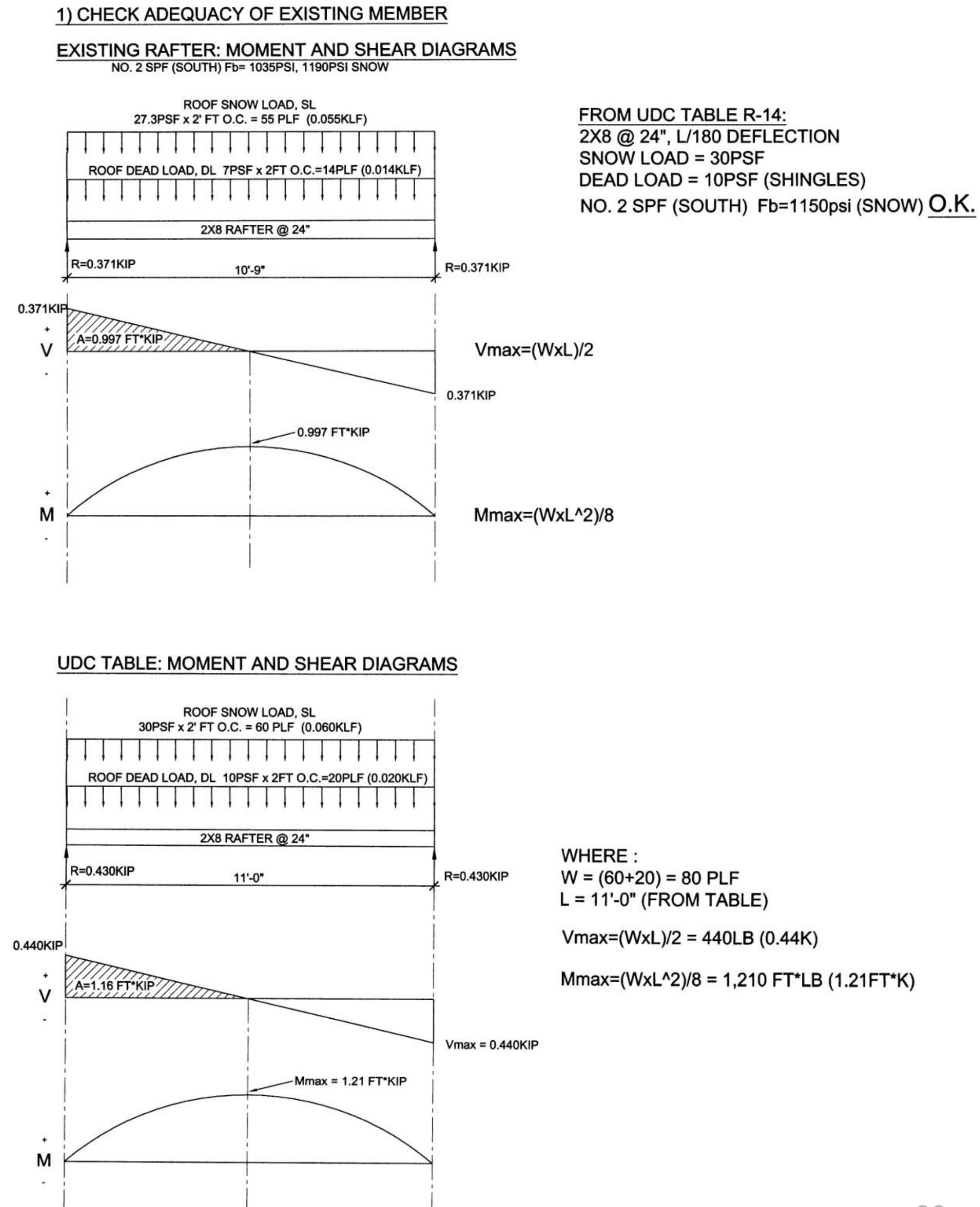
SL = 15X27.3 = 409 LBS OF SNOW (REDUCED FOR SLOPE)

DL PANEL = 44 LB

DL RAIL = 1PLF

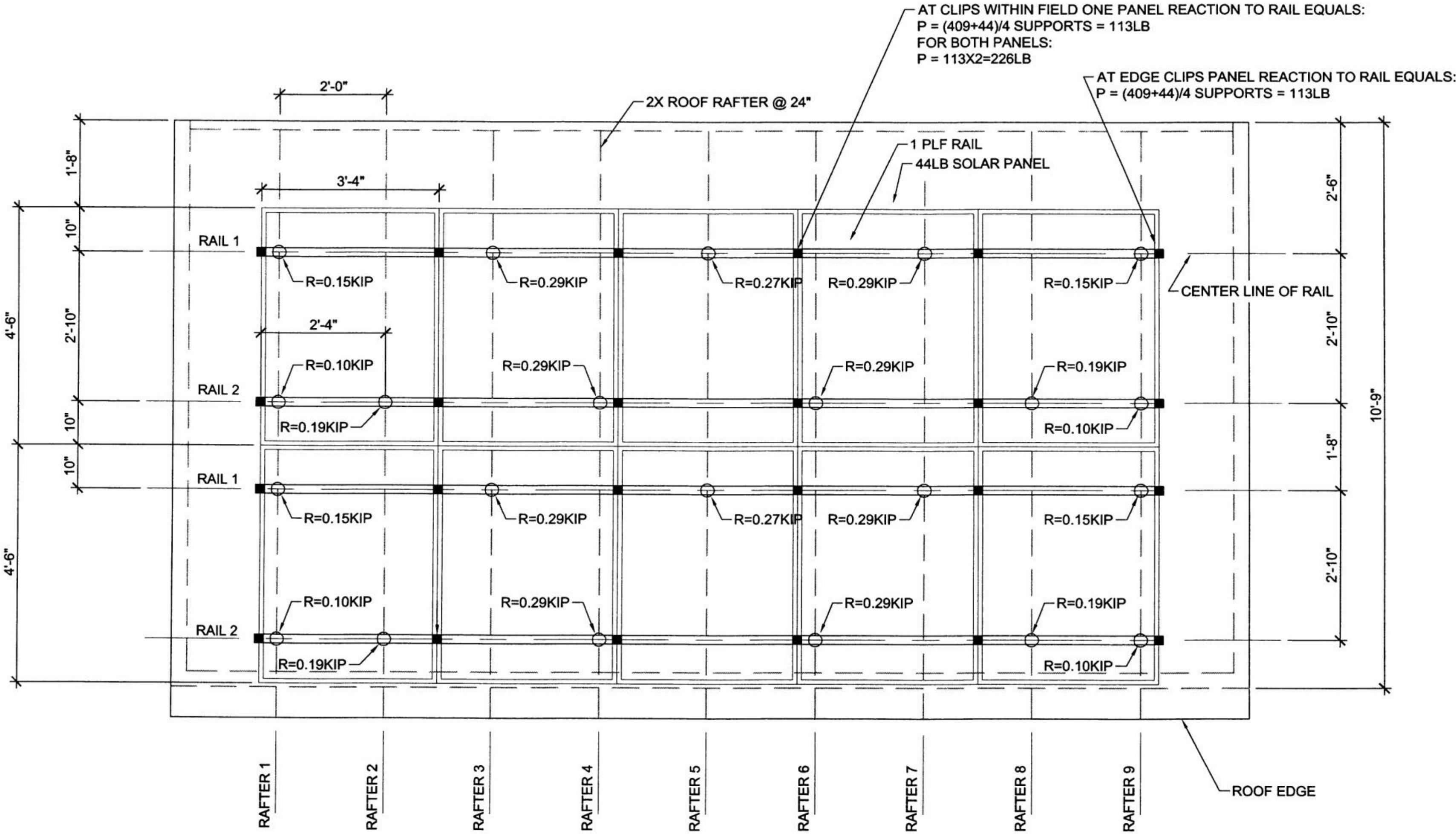
Example 3 – Flush Mounted PV System on Rails – Rafter Roof

- Many structural design manuals have beam diagrams and formulas for various static loading conditions such as $M_{max}=(WL^2)/8$



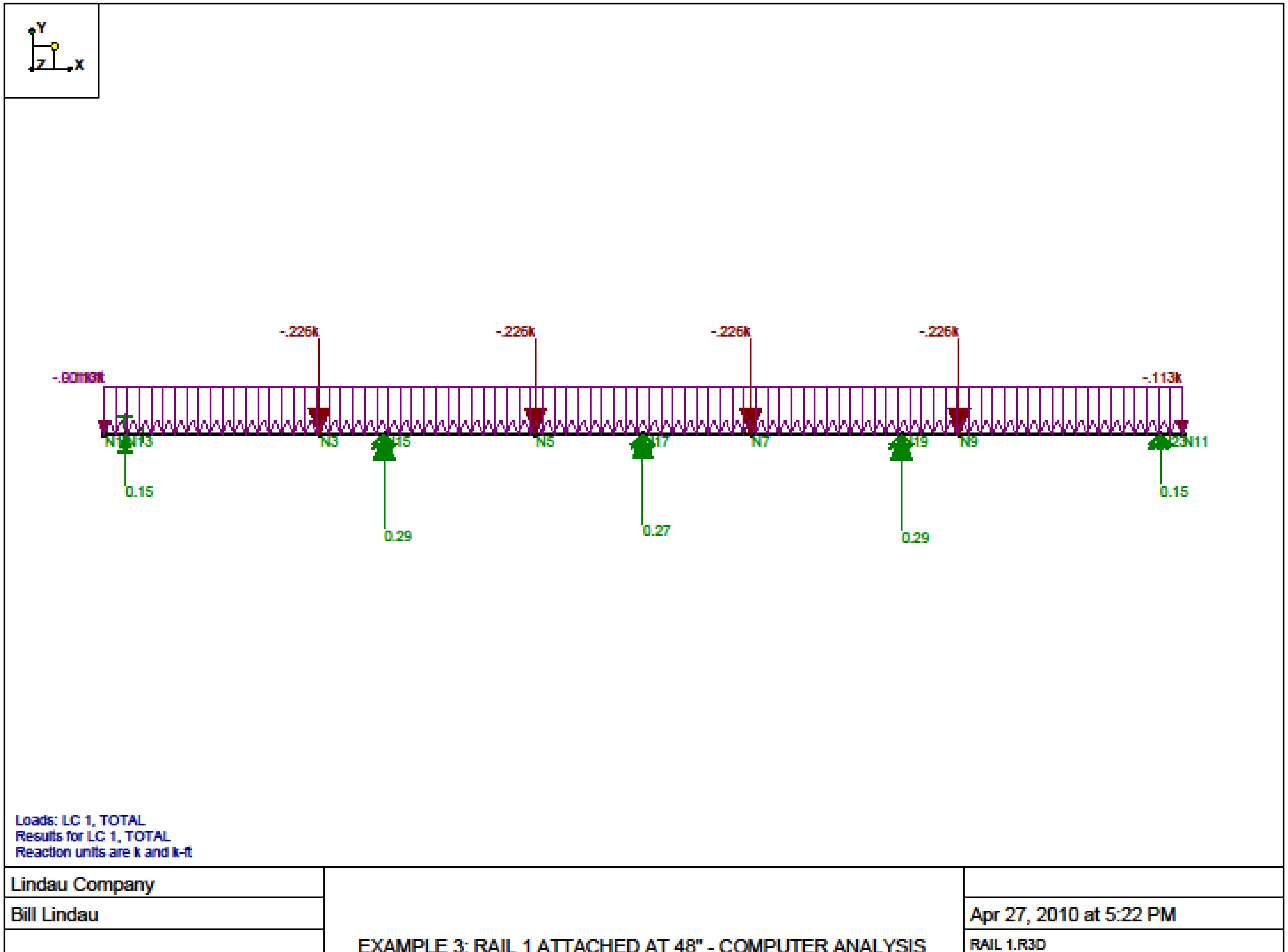
Example 3 – Flush Mounted PV System on Rails – Rafter Roof

- The rail reactions shown here have been computed by the use of analysis software because the rail is continuous over its supports and indeterminate to solve

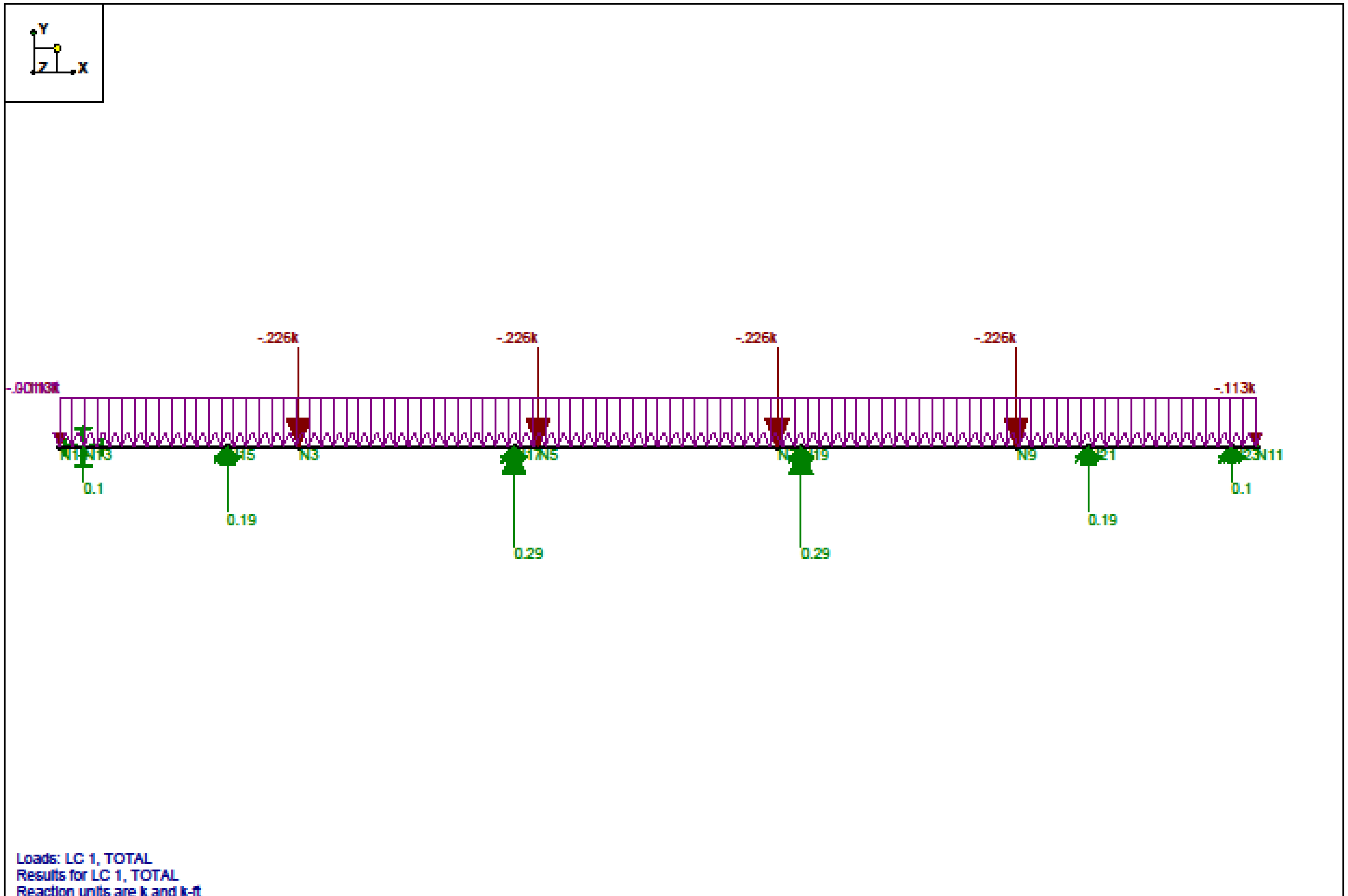


ROOF PLAN
RAILS SUPPORTED AT 48in O.C.

Example 3 – Flush Mounted PV System on Rails – Rafter Roof

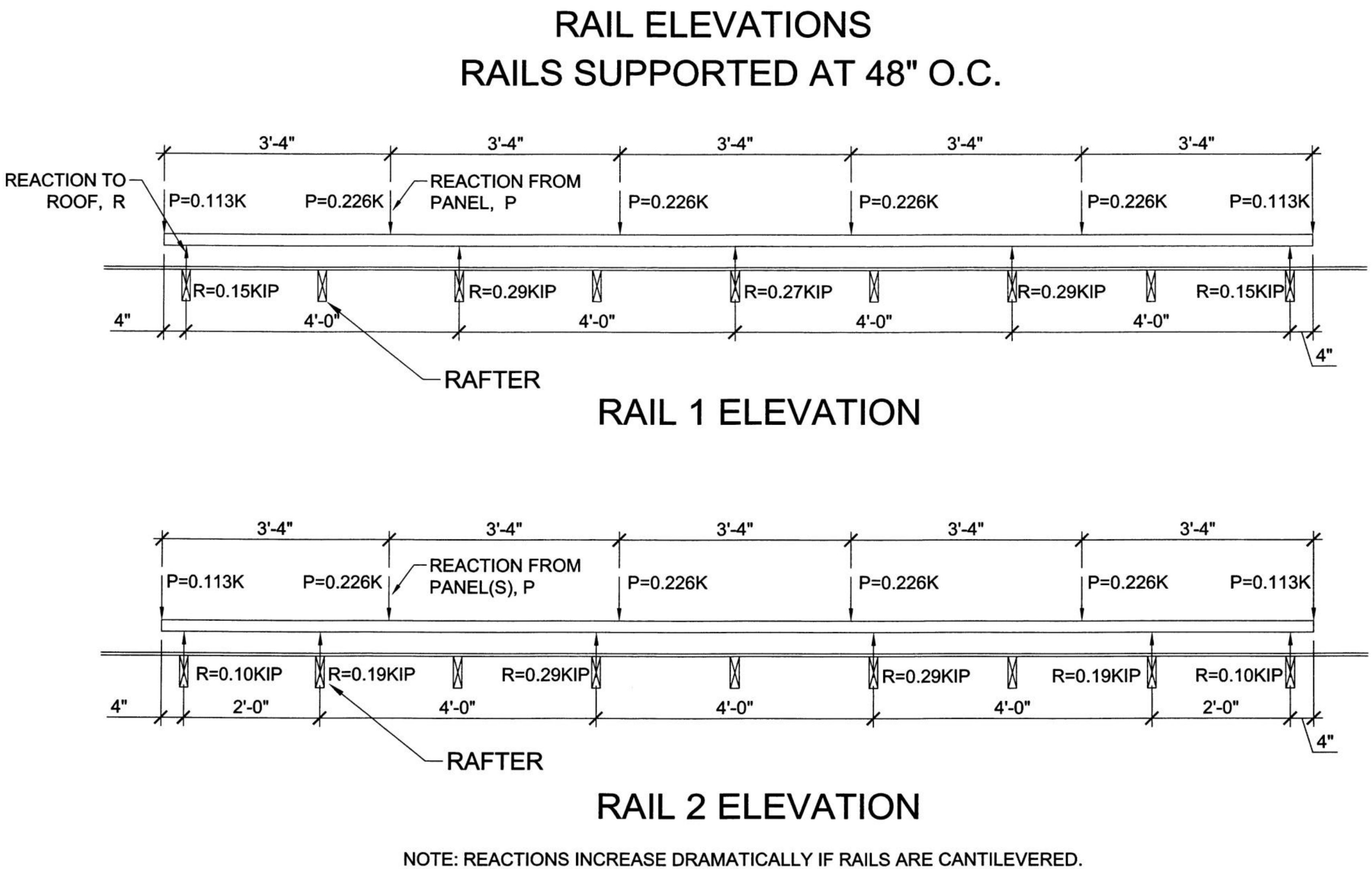


Example 3 – Flush Mounted PV System on Rails – Rafter Roof



Lindau Company		
Bill Lindau		Apr 27, 2010 at 5:25 PM
	EXAMPLE 3: RAIL 2 ATTACHED AT 48in O.C. - COMPUTER ANALYSIS	RAIL 2.R3D

Example 3 – Flush Mounted PV System on Rails – Rafter Roof



Example 3 – Flush Mounted PV System on Rails – Rafter Roof

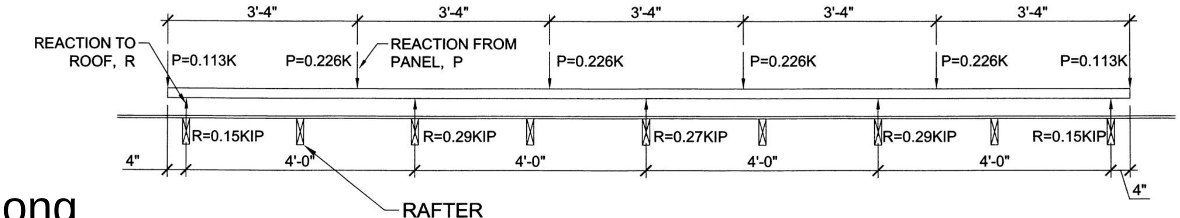
- Approximate methods include:

  a. Dividing the load among the tributary areas of its supports

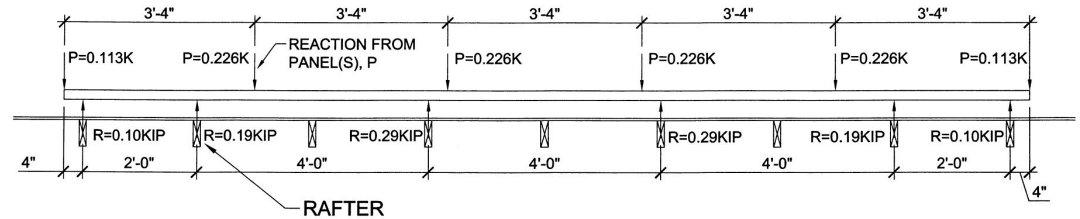
  b. Treating all spans as simple spans and using summation of moments and the summation of forces in the vertical direction to solve for the reactions

- A conservative approach should be taken when using approximate methods

RAIL ELEVATIONS
RAILS SUPPORTED AT 48" O.C.



RAIL 1 ELEVATION



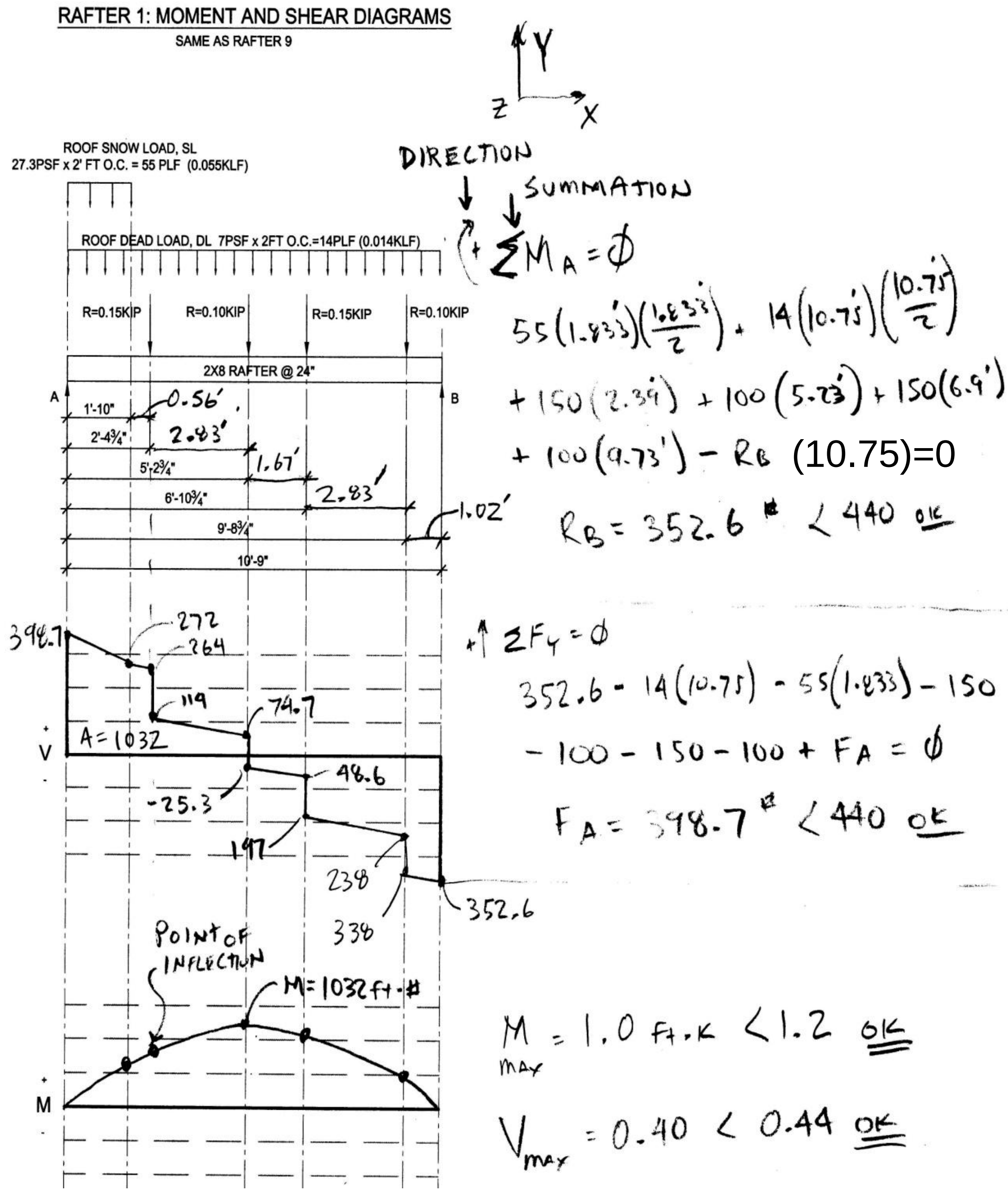
RAIL 2 ELEVATION

NOTE: REACTIONS INCREASE DRAMATICALLY IF RAILS ARE CANTILEVERED.

Example 3 – Flush Mounted PV System on Rails – Rafter Roof

Simple Spans: single beam supported at each end (also works for simple cantilevers with some challenges)

- Find R_B by summing moments about support A
- Find R_A by summing vertical forces
- Chart shear
- Area under shear ("V") curve as one moves from left to right creates the moment ("M") curve
- The slope of the Moment curve at any point represents the rate of change in shear
- Moment curve changes direction where shear curve crosses axis



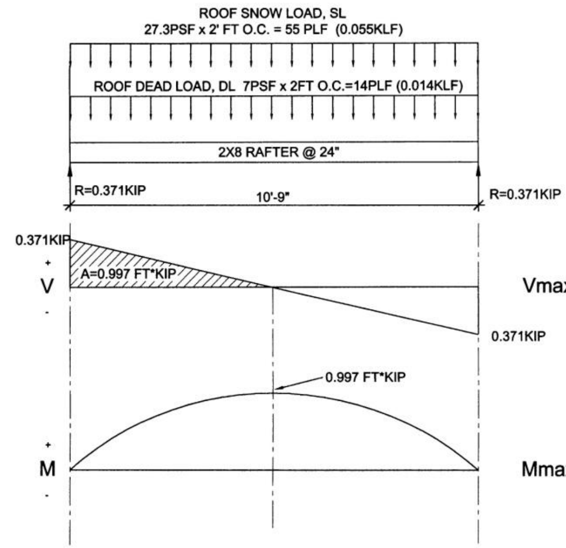
Example 3 – Flush Mounted PV System on Rails – Rafter Roof

- Compare resulting maximum Moments and Shears to the design Moment and Shears.

1) CHECK ADEQUACY OF EXISTING MEMBER

EXISTING RAFTER: MOMENT AND SHEAR DIAGRAMS

NO. 2 SPF (SOUTH) Fb= 1035PSI, 1190PSI SNOW

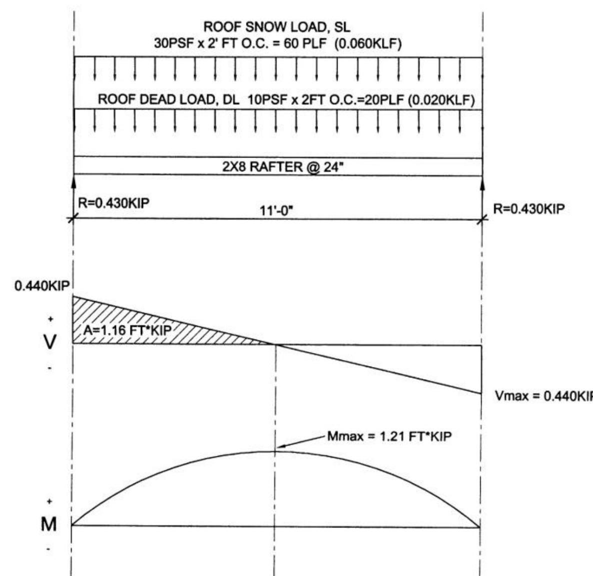


FROM UDC TABLE R-14:
2X8 @ 24", L/180 DEFLECTION
SNOW LOAD = 30PSF
DEAD LOAD = 10PSF (SHINGLES)
NO. 2 SPF (SOUTH) Fb=1150psi (SNOW) O.K.

Vmax=(WxL)/2

Mmax=(WxL^2)/8

UDC TABLE: MOMENT AND SHEAR DIAGRAMS



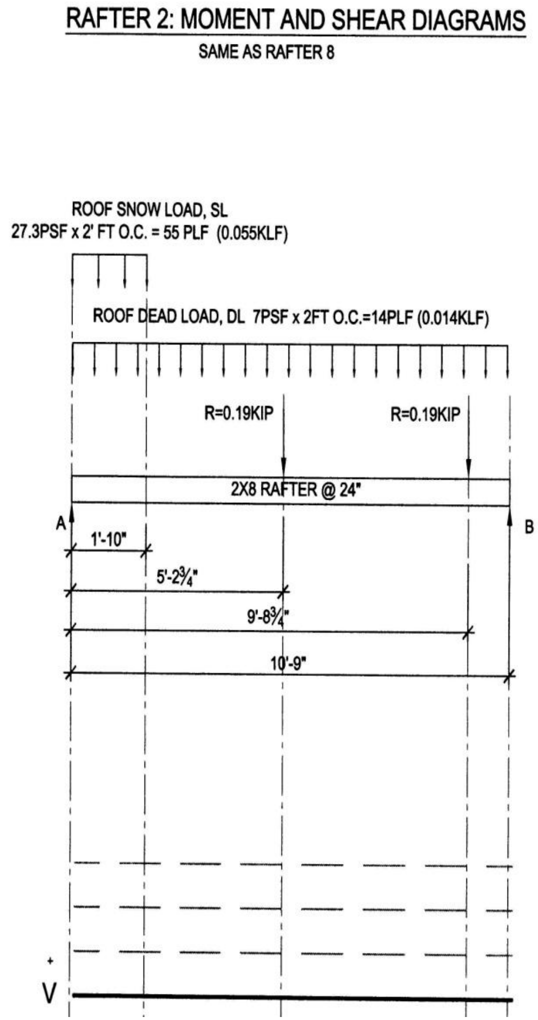
WHERE :
W = (60+20) = 80 PLF
L = 11'-0" (FROM TABLE)

Vmax=(WxL)/2 = 440LB (0.44K)

Mmax=(WxL^2)/8 = 1,210 FT*LB (1.21FT*K)

Example 3 – Flush Mounted PV System on Rails – Rafter Roof

Start the analysis with the rafters supporting the most load and similar members with less load and the same load configuration can be evaluated by comparison



BY OBSERVATION:

$M_{MAX} \ll M_{MAX}$ RAFTER 4

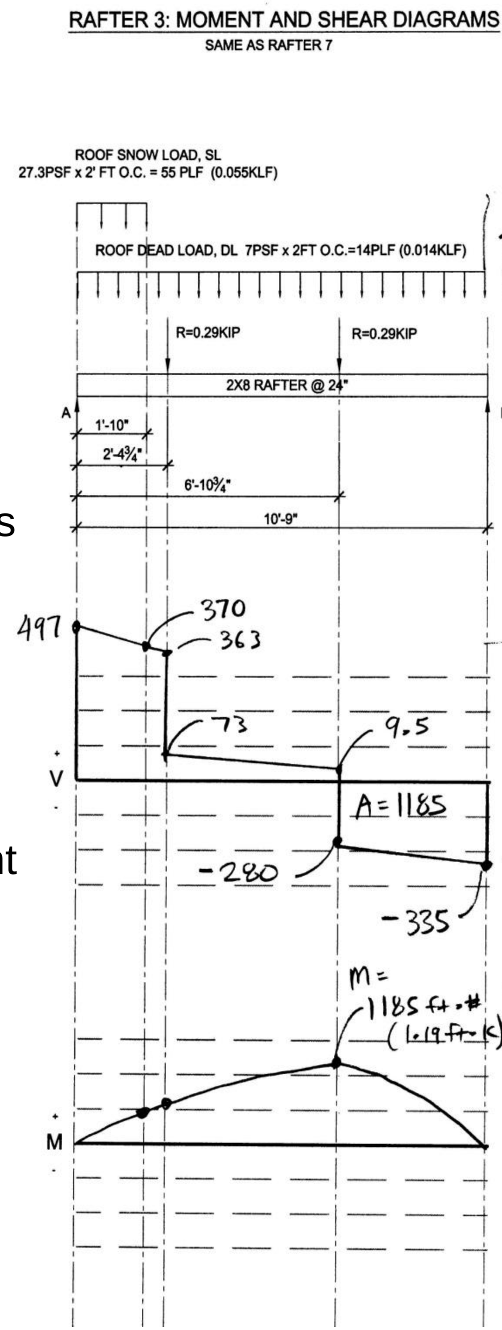
$V_{MAX} \ll V_{MAX}$ RAFTER 4

<u>OK</u>

Example 3 – Flush Mounted PV System on Rails – Rafter Roof

Simple Spans: single beam supported at each end (also works for simple cantilevers with some challenges)

- Find R_B by summing moments about support A
- Find R_A by summing vertical forces
- Chart shear
- Area under shear ("V") curve as one moves from left to right creates the moment ("M") curve
- The slope of the Moment curve at any point represents the rate of change in shear
- Moment curve changes direction where shear curve crosses axis



$\circlearrowleft + \Sigma M_A = \phi$

$55(1.833)\left(\frac{1.833}{2}\right) + 14(10.75)\left(\frac{10.75}{2}\right)$

$+ 290(2.93') + 290(6.9')$

$- R_B(10.75) = \phi$

$R_B = 334.5^{\#}$ OK

$\uparrow + \Sigma F_Y = \phi$

$334.5 - 55(1.833) - 14(10.75)$

$- 290 - 290 + R_A = \phi$

$R_A = 496.8^{\#} > 440$ NG

$M_{MAX} = 1.19$ ft·k < 1.21 ft·k

OK

$V_{MAX} = 0.50$k > 0.44k

NG

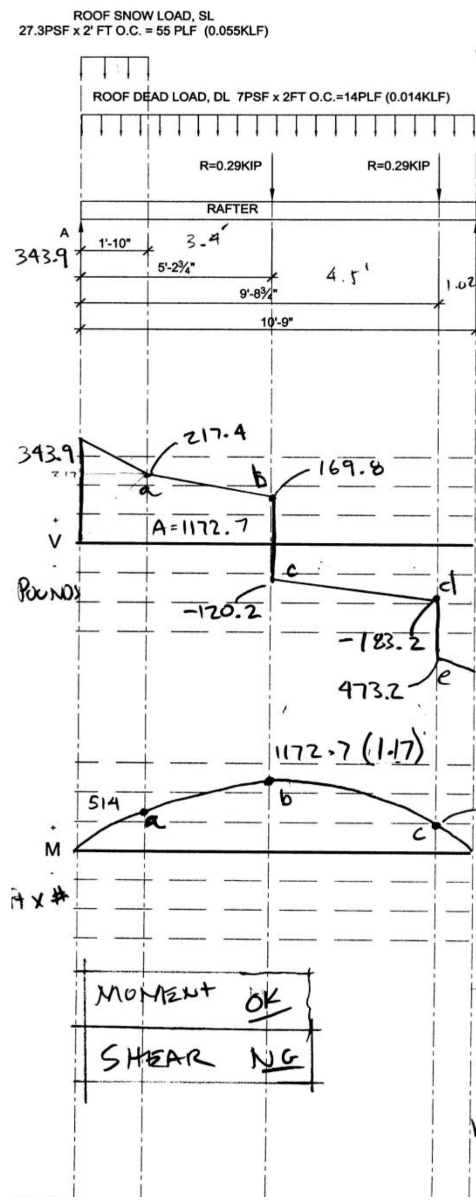
Example 3 – Flush Mounted PV System on Rails – Rafter Roof

Simple Spans: single beam supported at each end (also works for simple cantilevers with some challenges)

- Find R_B by summing moments about support A
- Find R_A by summing vertical forces
- Chart shear
- Area under shear ("V") curve as one moves from left to right creates the moment ("M") curve
- The slope of the Moment curve at any point represents the rate of change in shear (V)
- Moment curve changes direction where shear curve crosses axis

RAFTER 4: MOMENT AND SHEAR DIAGRAMS

(SAME AS RAFTER 6)



$\circlearrowleft + \sum M_A = 0$; $55(1.833)\left(\frac{1.833}{2}\right) + 14(10.75)\frac{10.75}{2}$

$+ 290(5.23) + 290(9.73)$

$- R_B = \emptyset$

$R_B = 487.4^{\#} > 440$ NG

$+\uparrow \sum F_Y = \emptyset \quad 487.4 - 55(1.833) - 14(10.75)$

$- 290 - 290 + R_A = \emptyset$

$R_A = 343.9^{\#}$

POINTS ON SHEAR (V) DIAGRAM:

a) $343.9 - (55+14)(1.833) = 217.4$

b) $217.4 - 14(3.4') = 169.8$

c) $169.8 - 290 = -120.2$

d) $-120.2 - 14(4.5) = -183.2$

e) $-183.2 - 290 = -473.2$

f) $-473.2 - 14(1.02) = 487.4$

POINTS ON MOMENT DIAGRAM:

a) $343.9\left(\frac{1.833}{2}\right) + 217.4\left(\frac{1.833}{2}\right) = 514.4$ ft·#

b) $514.4 + 217.4\left(\frac{3.4}{2}\right) + 169.8\left(\frac{3.4}{2}\right) = \boxed{1172.7 \text{ Ft \#}}$

c) $1172.7 - 120.2\left(\frac{4.5}{2}\right) - 183.2\left(\frac{4.5}{2}\right) = 490$ ft #

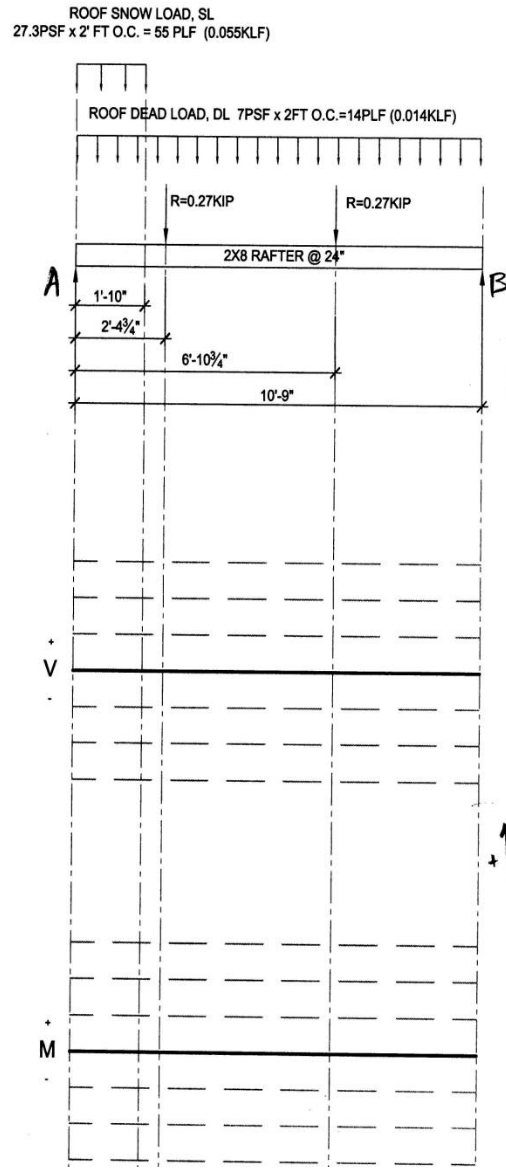
Example 3 – Flush Mounted PV System on Rails – Rafter Roof

Start the analysis with the rafters supporting the most load and similar members with less load and the same load configuration can be evaluated by comparison

- Do not assume that because the member satisfies the moment criteria that it will satisfy the shear criteria

RAFTER 5: MOMENT AND SHEAR DIAGRAMS

UNIQUE



THIS RAFTER HAS LESS LOAD ON IT THAN RAFTER #3 BUT WITH THE SAME CONFIGURATION

THUS: MOMENT IS OK
CHECK SHEAR

$$\circlearrowleft^{+} \Sigma M_A = \phi$$

$$55(1.833)\left(\frac{1.833}{2}\right) + 14(10.75)\left(\frac{10.75}{2}\right) + 270(2.39') + 270(6.9') - R_B(10.75') = \phi$$

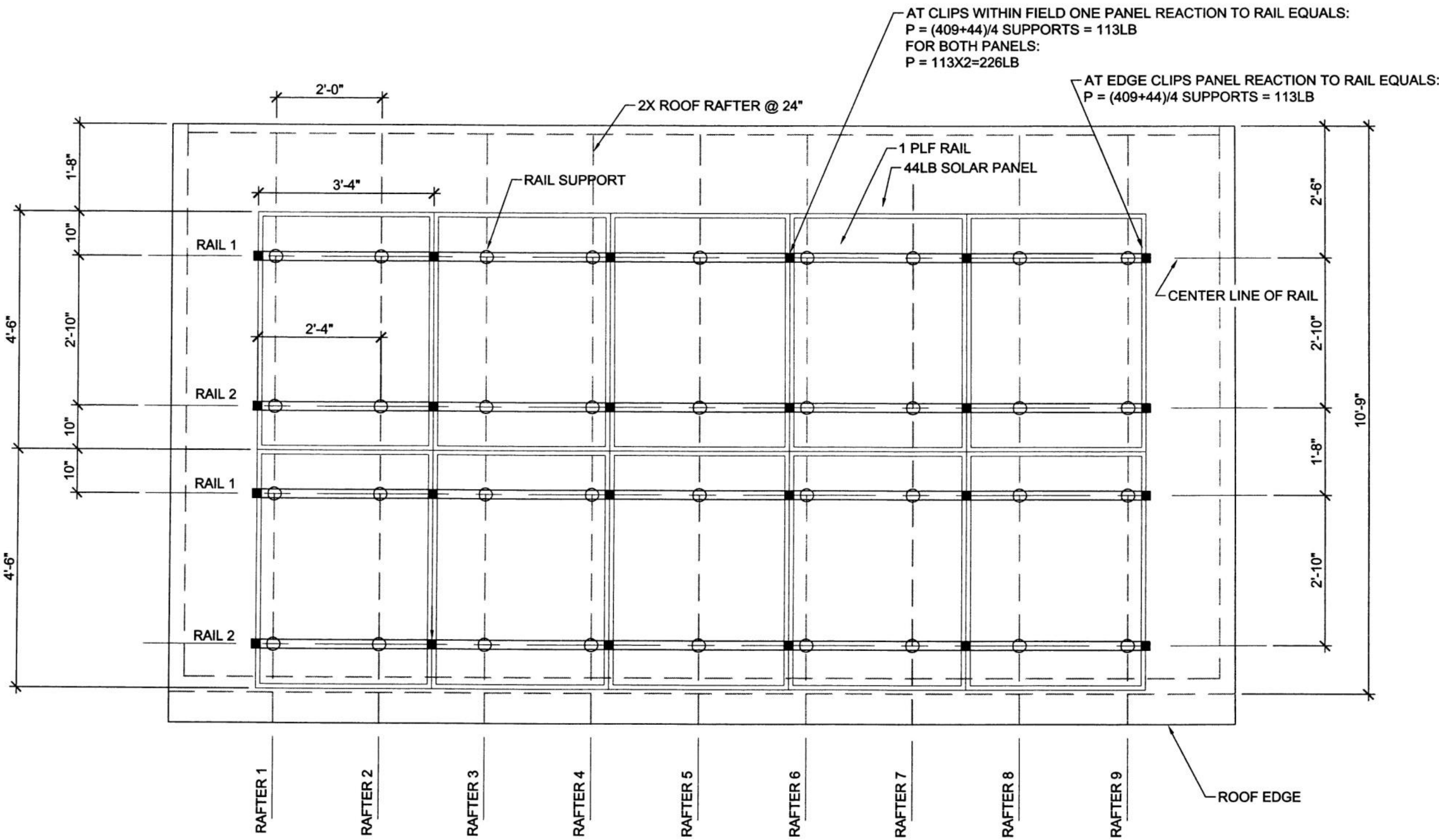
$$R_B = 317.2$$

$$+\uparrow \Sigma F_Y = \phi$$

$$317.2 - 55(1.833) - 14(10.75) - 270 - 270 + R_A = \phi$$

$$R_A = 474.1^{\#} > 440 \ \underline{NG}$$

Example 3 – Flush Mounted PV System on Rails – Rafter Roof

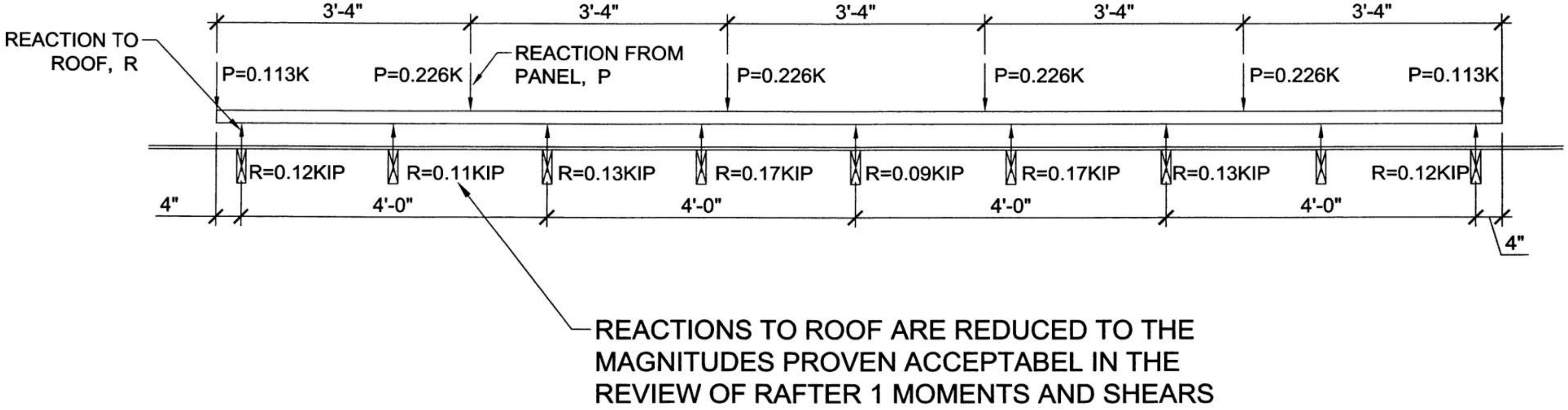


ROOF PLAN
RAILS SUPPORTED AT 24in O.C.

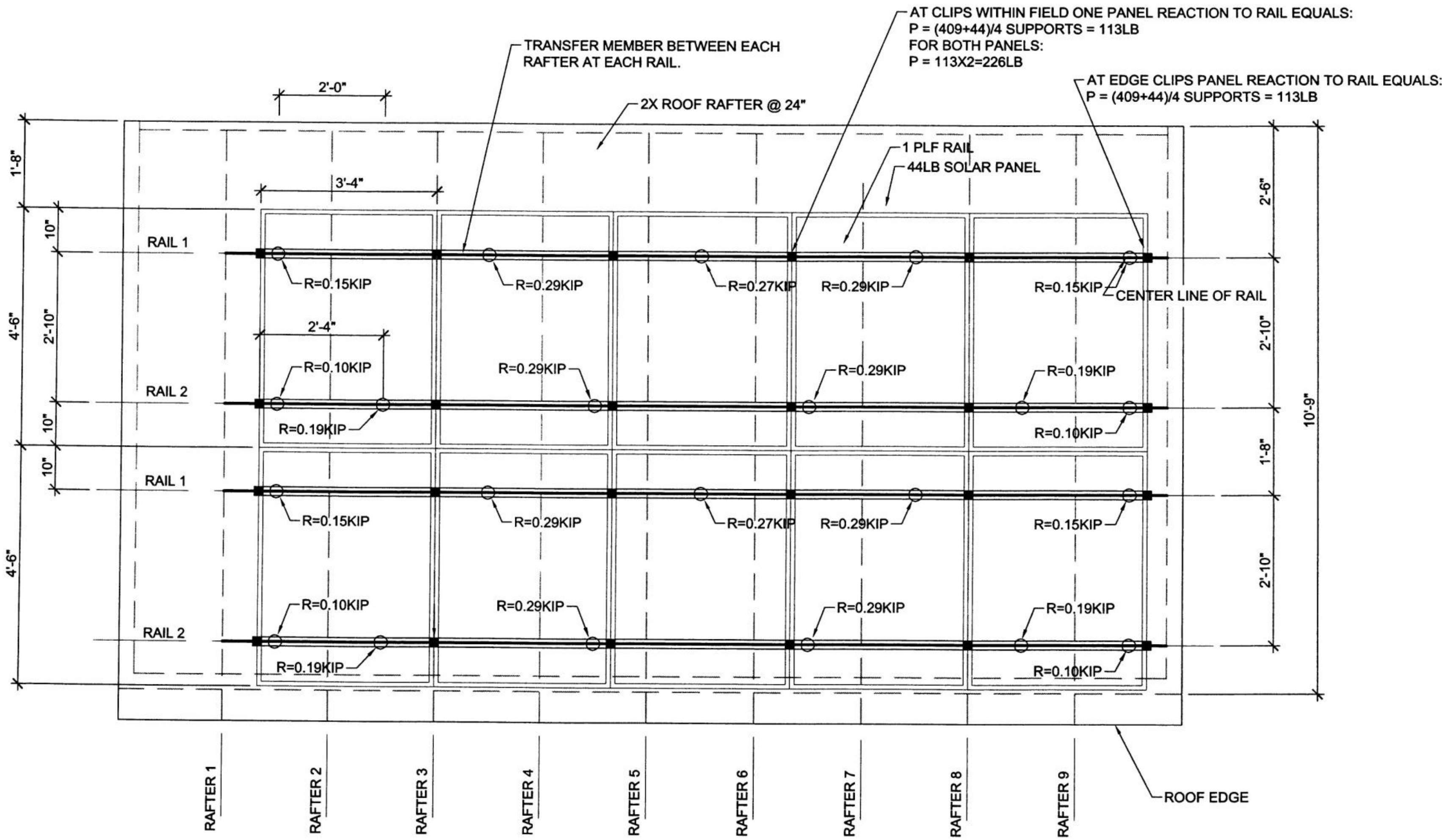
Example 3 – Flush Mounted PV System on Rails – Rafter Roof

RAIL ELEVATION

RAILS SUPPORTED AT 24" O.C.



Example 3 – Flush Mounted PV System on Rails – Rafter Roof

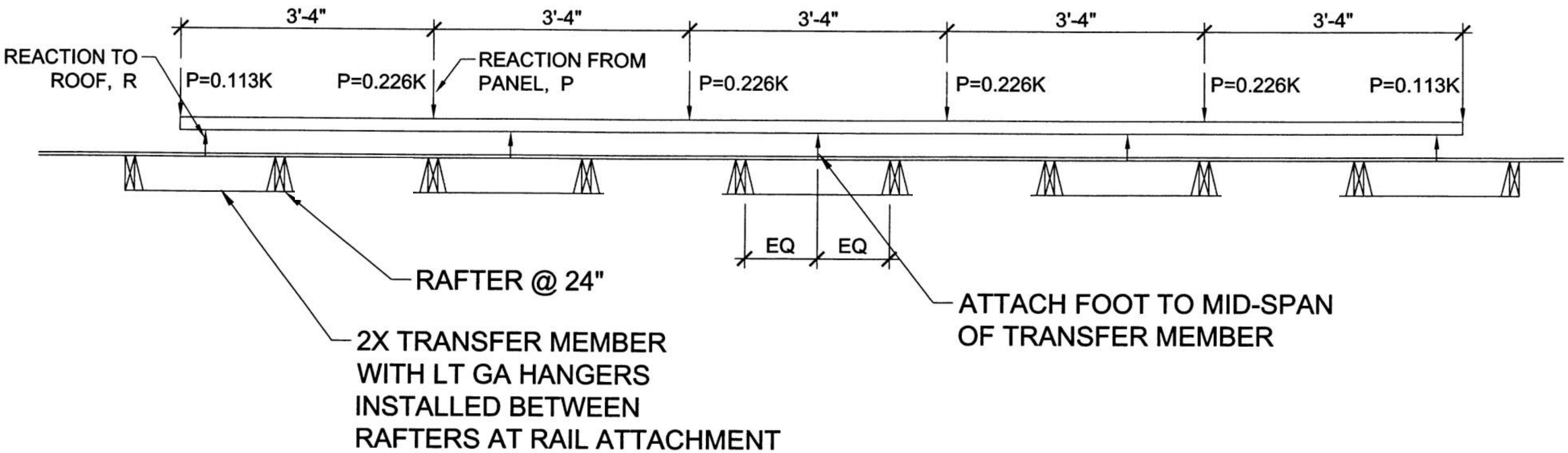


ROOF PLAN
RAILS SUPPORTED AT 48in O.C. - TRANSFER MEMBERS BETWEEN RAFTERS

Example 3 – Flush Mounted PV System on Rails – Rafter Roof

RAIL ELEVATION

RAILS SUPPORTED AT 48" O.C.
WITH TRANSFER MEMBERS INSTALLED BELOW



RESULTING LOADS TO RAFTERS IS ALMOST THE SAME AS IF THE RAILS WERE SUPPORTED AT 24in O.C.

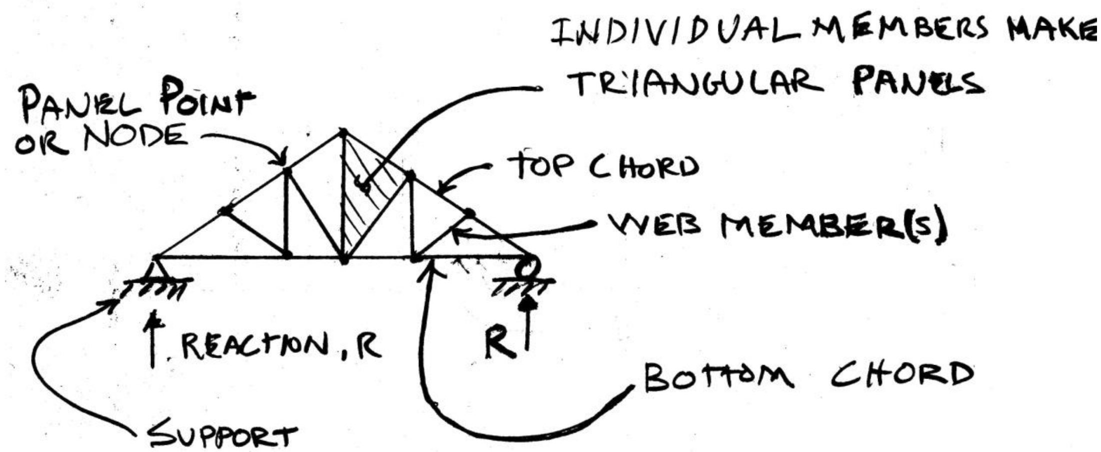
Example 4 – Flush Mounted PV System on Rails – Truss Roof

1. Determine original construction design loads
   - Manufacturer supplied calculations
   - Engineering analysis
   - Original documents
2. Calculate rail reactions, load configuration, and tabulate dead loads
   - If rail reactions fall between nodes, determine maximum moment (M) and shear (V) of members directly supporting rails OR
   - If rail reactions fall at nodes, determine reactions at truss nodes affected
3. Make comparison & judgment

Example 4 – Flush Mounted PV System on Rails – Truss Roof

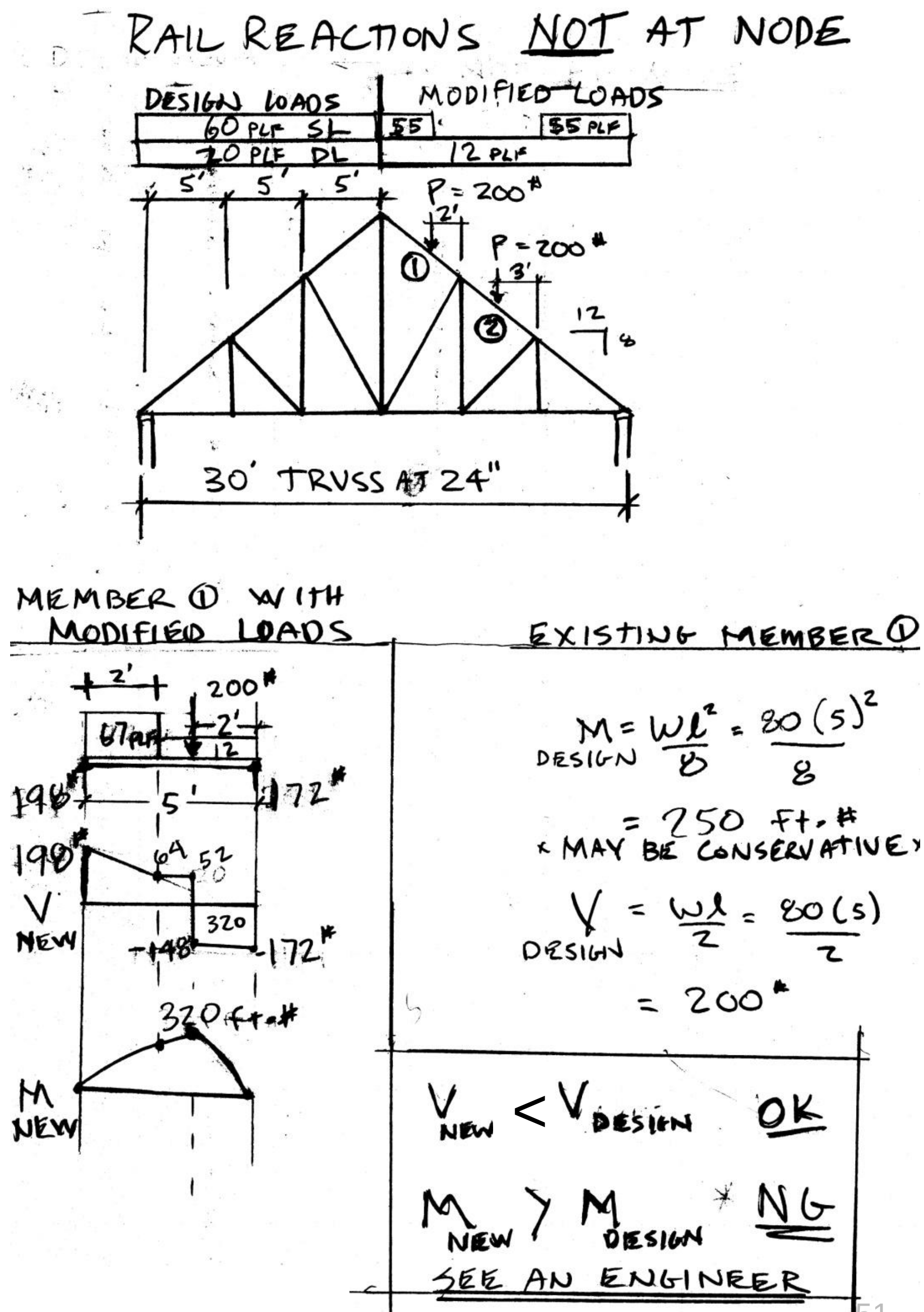
Review of Trusses:

- Capacities are determined through a lengthy process
- Usually performed by a truss supplier



Example 4 – Flush Mounted PV System on Rails – Truss Roof

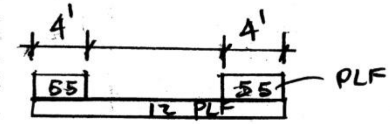
Divide top chord into simple spans and use summation of moments and summation of vertical forces to determine M and V

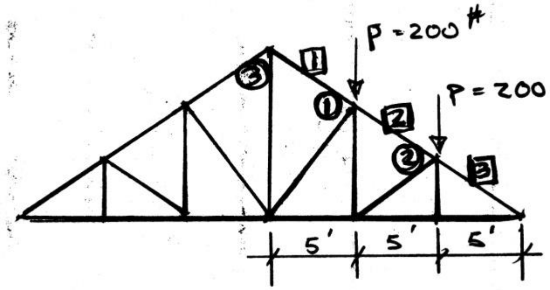


Example 4 – Flush Mounted PV System on Rails – Truss Roof

Trusses are ideally loaded at nodes / panel points

RAIL REACTION AT NODE





NODE ①

DESIGN REACTION AT N① (FROM MEMBERS $\boxed{1}$ & $\boxed{2}$) $= (20+60)\frac{5'}{2} \times 2$

$= 400^{\#}$

NEW LOAD AT N①

REACTION FROM $\boxed{1}$

$+\Sigma M_{②} = \phi \quad 55(4)\left(\frac{4}{2}\right) + 12(5)\left(\frac{5}{2}\right) - R_{①}(5) = \phi$

$R_{1} = 118^{\#}$

REACTION FROM $\boxed{2}$

$\Sigma M_{②} = \phi \quad 12(5)\left(\frac{5}{2}\right) - R_{1}(5) = \phi$

$R_{1} = 30^{\#} \quad \left(\frac{w\ell}{2}\right)$

TOTAL REACTION AT N①

$118^{\#} + 30^{\#} + 200^{\#} = 348^{\#} < 400^{\#}$ OK

Example 4 – Flush Mounted PV System on Rails – Truss Roof

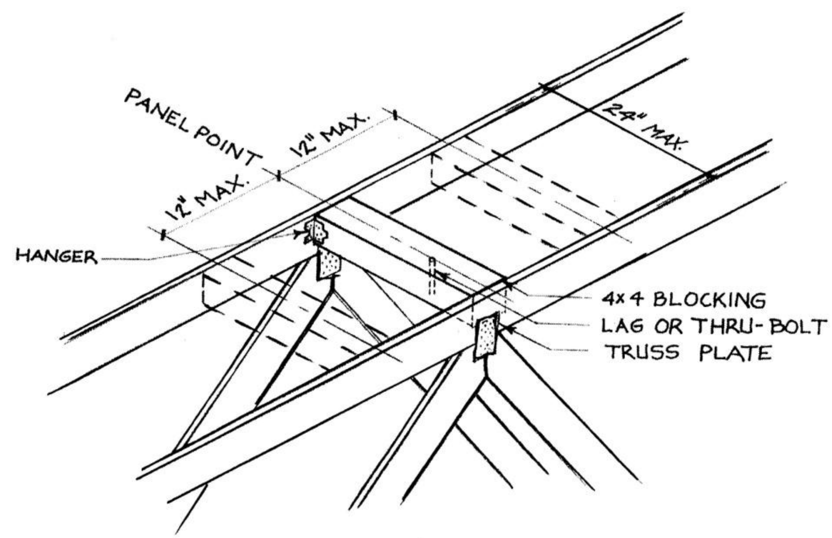
Courtesy of Alan Harper
Plan Review Specialist III
City of Madison
Building Inspection

Reinforcing roof system great simplifies the approval process

CRITERIA FOR SIMPLIFIED APPROVALS OF ROOFTOP SOLAR COLLECTOR INSTALLATIONS ON TRUSSES

The method shown below is approved as an acceptable method for supporting a solar installation on a trussed roof. The following criteria must be met for this system.

1) The truss spacing must not exceed 24 inches on center.
2) A minimum of 4x4 lumber is used as a brace between trusses.
3) The brace is within 12 inches of a panel point on the top chord of the truss.
4) The support legs for the solar installation are lag or thru-bolted to the brace.
5) The brace is attached to the trusses with mechanical fasteners (hangers) sized to carry the required uplift and down loads.



Notes:

1. A panel point is where the webs meet the chord. There is a truss plate at this location and it is the best location to install the brace. The mangers can be nailed through the truss plates.
2. Several manufacturers make face-mount hangers that are suitable for this installation. Hangers similar to the one shown in the diagram have a capacity of approximately 280 pounds each. If two are installed at each end, this gives a capacity of 1,120 pounds for this support.

Summary of Examples

Example 1 – Flush Mounted Solar Hot Water

Flashed Into Roofing – NO RAILS – Rafter Roof

- **Evenly distributed loads are usually within the dead load capacity of the roof system**

Example 2 – Flush Mounted Solar Hot Water

Flashed Into Roof – NO RAILS – Truss Roof

- **Evenly distributed loads are usually within the dead load capacity of the roof system**

Example 3 – Flush Mounted PV System

Supported by Rails – Rafter Roof

- **Depending on the rail support configuration point loads can easily be in excess of the roofs capacity.**
- **Distributing these loads over members at 24” will <u>almost</u> always be acceptable**

Example 4 – Flush Mounted PV System

Supported by Rails – Truss Roof

- **Attachment or distribution to truss panel points/nodes may be necessary**

Grading Existing Lumber

#2 Structural Framing

Source: National Grading Rule for Dimension Lumber, "Standard Grading Rules for West Coast Lumber No. 17" (2004 edition), West Coast Lumber Inspection Bureau

Courtesy of Alan Harper
Plan Review Specialist III
City of Madison
Building Inspection

IDENTIFYING #2 STRUCTURAL FRAMING

"Old lumber so much better than new lumber." We hear this or a similar quote quite often. However, is this true and, whether or not it is true, can reasonable structural design values be found for old installed lumber? To answer the first part, old lumber often came from older growth trees. It is typically denser and "looks better" because it often came from the denser and more consistent center of the tree. On the other hand, these trees were not groomed the way new lumber trees are so many times large knots from large braches are found in the board and sometimes the grain curves and becomes perpendicular to the length of the board. Both of these defects can severely weaken the board.

Other problems with older wood occur from aging. As the wood ages the cells break down. Depending on atmospheric conditions and the presence of insects, mold, and fungi, this breakdown can be slow to rapid.

The question that needs to be answered is, "Just how good the wood in this building?"

Often in older homes construction lumber has no grade stamp because the lumber was installed prior to the practice of lumber grading. Reasonable structural properties may still be obtained for this lumber by comparing it to values used for commonly used current construction lumber.

The most common "typical" lumber used in Wisconsin is #2 SPF. Structural properties for this grade and species of lumber can be found in the National Design Specification For Wood Construction published by the American Wood Council.

By comparing the observations of the installed lumber in the field to the following criteria for #2 structural framing, a determination can be made whether or not the installed lumber meets these criteria. If the installed lumber meets these criteria, the design values can be taken as those for #2 SPF.

Without the observer being rigorously trained in lumber grading, a higher grade should not be assumed. If the installed lumber does not meet the criteria shown here, the pieces not meeting the criteria should be assumed to have no structural value.

Grading Existing Lumber

#2 Structural Framing

Source: National Grading Rule for Dimension Lumber, "Standard Grading Rules for West Coast Lumber No. 17" (2004 edition), West Coast Lumber Inspection Bureau

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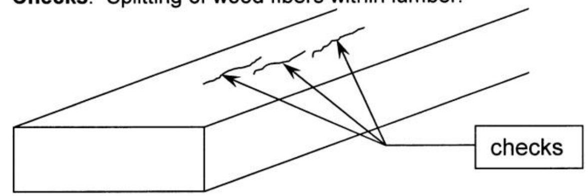
IDENTIFYING #2 STRUCTURAL FRAMING

Checks: Splitting of wood fibers within lumber.



Criteria for #2 grade: Not limited. (Full depth checks at ends are splits.)

Knots: Part of a limb or branch that has been surrounded by growth.
Criteria for #2 grade: Well spaced knots of any quality are permitted in sizes not to exceed the following table or equivalent displacement:

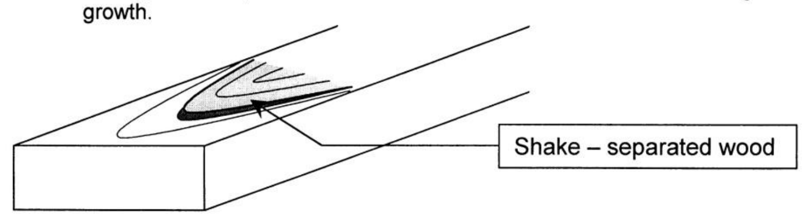
Well spaced: The sum of the sizes of all knots in any 6" of length of a piece must not exceed twice the size of the largest knot permitted. More than one knot of maximum permissible size must not be in the same 6" length and the combination of knots must not be serious.

Nominal width of joist or rafter	Knot at edge of wide face	Knot in center of wide face	Holes
4"	1-1/4"	2"	1-1/4"
5"	1-5/8"	2-3/8"	1-3/8"
6"	1-7/8"	2-7/8"	1-1/2"
8"	2-1/2"	3-1/2"	2"
10"	3-1/4"	4-1/4"	2-1/2"
12"	3-3/4"	4-3/4"	3"
14"	4-1/8"	5-1/4"	3-1/2"
16"	4-3/8"	5-7/8"	4-1/2"

For the narrow edge, ½ of the knot size is allowed.
One hole is allowed per 2 lineal feet.

Pitch and bark pockets: Well-defined openings between rings of annual growth which develops during the growth of a tree. The pocket contains pitch or bark.
Criteria for #2 grade: Not limited

Shake: A lengthwise separation of the wood which occurs between or through the rings of annual growth.



Criteria for #2 grade: If through at ends, limited as splits. Away from ends through shakes up to 2 feet long, well separated. If not through, single shakes shall not exceed 3 feet long or ¼ the length whichever is greater.

"Through," in this case, means from edge to edge on the same face.

Grading Existing Lumber

#2 Structural Framing

Source: National Grading Rule for Dimension Lumber, “Standard Grading Rules for West Coast Lumber No. 17” (2004 edition), West Coast Lumber Inspection Bureau

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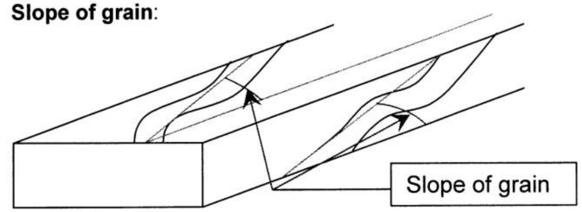
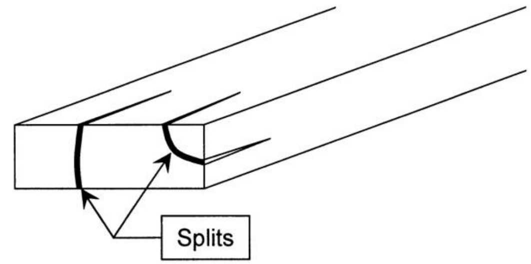
Slope of grain:



Criteria for #2 grade: Maximum 1 in 8

Splits: A separation of the wood through the piece to the opposite surface or to an adjoining surface due to the tearing apart of the wood cells.



Criteria for #2 grade: Equal in length to 1-1/2 times the width of the piece.

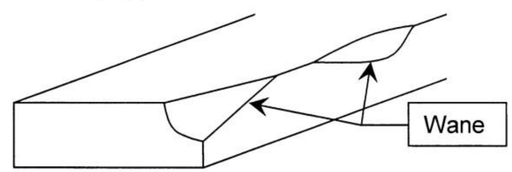
Unsound wood (excluding white speck):
Criteria for #2 grade: Not permitted in thicknesses over 2”. In 2” lumber, small spots or streaks of firm honeycomb or peck are limited to 1/6 the width. Any other unsound wood is limited to a spot 1/12 the width and 2” in length or equivalent smaller areas.

Honeycomb: A cellular separation that occurs in the interior of a piece of wood, usually along the wood rays.

Peck: Deterioration and softening caused by fungus.

White speck: A fungal organism that invades living softwoods but ceases to develop once the tree is cut. Lumber grading generally considers it a "cosmetic defect" and it may be found in framing lumber.

Wane: Bark or lack of wood from any cause, except eased edges, on the edge or corner of a piece of lumber.



Criteria for #2 grade: 1/3 the thickness and 1/3 the width full length, or equivalent on each face, provided that wane not exceed 2/3 the thickness or ½ the width for up to ¼ the length.

Source: National Grading Rule for Dimension Lumber, “Standard Grading Rules for West Coast Lumber No.17” (2004 edition), West Coast Lumber Inspection Bureau.

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Questions/Discussions

April 30, 2010

Structural Implications of Mounting Solar Panels on a Residential Wood Structure